Z/1. Zafar, M., Akram, H. & Yoshida, M., 1996. Major elements composition of Haro river Loess-paleosol deposits, Attock district, Punjab, Pakistan. Proceedings Geoscience colloquium, 14, 117-123.

The variation of chemical composition of the loess-paleosol deposits reveals that Fe, K, Al, and Mg contents are relatively high in the paleosol horizons than rest of the loess sequence, whereas Ca content is relatively low. Elemental ratios d SiO_2/Al_2O_3, and SiO_2/Fe_2O_3 generally decrease at paleosol horizons. These characteristics of chemical composition resemble to loess-paleosol deposits in Kashmir and China, it is applicable to identify paleosol horizon as well as paleoenvironmental condition in the area

Key words: Geochemistry, loess-paleosol deposits, Attock.

Z/2. Zafar, M., Murata, M., Khan, T., Ozawa, H. & Nishimura, H., 1998. Major and trace element composition of post-collisional, peralumonous Garam Chashma granite in Trans-Himalaya, northwestern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 221-222.

Garam Chashma granite belongs to a suit of granitoids of the Asian continental plate in the Hindu Kush Range (Trance Himalaya), northwestern Pakistan. It is located about 30-km northwest of Chitral and northern suture covering an area of about 300-km^2. The Garam Chashma granite is a discordant atid leucocratic rock, which intruded into peletic metasediments and amphibolites formed during Barrovian type metamorphism that took place between 40-25 Ma ago. A comparative age of 28-12 Ma has been suggested for the Garam Chashma granite which is same as for some of the Higher Himalaya leucogranites. Petrographically, the major rock forming minerals include quartz, plagioclase, K-feldspar, muscovite and biotite with subordinate garnet and tourmaline. Ratio of muscovite to biotite is not constant. All accessory mineral cordierite has also been reported in the area. Grain size ranges from fine to coarse grained. Texturally the rocks are massive, however, slight to moderate foliation marked usually by muscovite and biotite, especialy near the contact of intrusion can be observed. Aphtic and pegmatitic veins/dikes localising minerals such as garnet and tourmaline are widely spread through out the pluton. A total of about 72 rock samples were collected from the Garam Chashma area. Major and trace components (Ce, Cr, Nb, Ni, Pb, Rb, Sr, Th, Y, Zr, and Ba) were analyzed using X-ray fluorescence spectrometer. On the ternary discrimination diagram, for S and 1-type granites, oxide mole values of AI-Na-K, Ca and Fe+Mg predominantly plots on the S-type field suggesting sedimentary source for the Garam Chashma pluton. The silica concentration variation range is very small (71.91-7 6.0 8 wt %). A/CNK ratio is greater than 1 thereby conforming the peraluminous nature of the pluton. Almost all the major elements when plotted against silica, show some sort of depletion trend with increasing silica, whereas Na shows an enrichment trend. Minor depletion trend of K may represent an early formation of K-feldspar along with ferromagnesian minerals during crystalization History of the pluton. Depleting patterns of Ba, Nb, Sr, Ti, and P, commonly found in stibduction related magmatism, are observed. Decreasing K/Rb ratios in K/Rb versus Rb plot may be attributed to the fractionation of feldspars.

Furthermore, a chemical compositional comparison based on major and trace elements with two pre-collisional granitold bodies named Tirichmir and Kafristan in Trans Himalaya, located NE and SE of the Garam Chashma respectively, is also performed. Silica concentration ranges for Tirichmir (65.96-72.02 wt %) and Kafiristan (64.26-75.72) are higher than that of the Garam Chasma pluton, because of their predominant granodioritic nature. A/CNK plots reveal peralumonous and meta-peraluminous characteristics of Tirichmir and Kafiristan plutons respectively. In Si versus K plot, potasium shows an enrichment trend in Tirichmir and Kafiristan pltitons when compared to Garam Chashma. Ca and Fe concentrations are higher than those for the Garam Chasma pluton because of the presence of more mafic minerals. However, higher Ca and Fe concentrations and lower Mg concentration in the Kafiristan pluton than the Tirichmir pluton, are probably due to the higher concentraions of hornblend in the former. Pb, Rb, Y, Th and Zr concentrations show enrichment in mafic fractions of both the granitoids. A positive correlation of Ba and Sr represents fractionation of mineral phases such as plagioclase and K-feldapar of the Garam Chasma pluton and hornblend, feldspars and blotite of the Tirichmir and Kafiristan pluton.

Key words: Geochemistry, peraluminous granite, Garam Chashma, Chitral, Hindukush.

Z/3. Zafar, M., Murata, M., Khan, T., Ozawa, H., & Nishimura, H., 2000a. K–Ar biotite ages from Miocene post–collisional Garam Chashma leucogranite, eastern Hindu Kush Range (Trans–Himalayas), northwestern Pakistan. Journal of Mineralogical and Petrological Sciences, 95, 101–106.

Key words: Geochronology, K-Ar dating, Leucogranite, Garam Chashma, Chitral, Hindukush.

Z/4. Zafar, M., Murata, M., Khan, T., Ozawa, H., & Nishimura, H., 2000b. Major and trace elements composition of post-collisional, prealuminous Garam–Chashma granite in Trans–Himalaya, northwestern Pakistan. Journal of Mineralogical and Petrological Sciences, 95, 173–181.

Key words: Geochemistry, Peraluminous granite, Garam Chashma, Chitral, Hindukush

Z/5. Zaheer, B., 1990-91. Structure, stratigraphy and petrography of the western limb of the Hazara-Kashmir Syntaxis, Garhi Habibullah-Shinkiari area, Northern Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 105p.

The Garhi Habibullah-Shinkiari area lies along the western limb of the major northwest plunging antiformal structure known as the Hazara-Kashmir syntaxis. The 293 km^2 area has been mapped in this study. The western limb of the Hazara-Kashmir syntaxis has been divided into four fault-bounded tectonostratigraphic zones. These are named as the Muzaffarabad-Balakot zone, the Garhi Habibullah-Abbottabad zone, the Panjal zone and the Mansehra zone. These zones belong to different tectonic and stratigraphic provinces which have been juxtaposed during the Himalayan thrusting. The Muzaffarabad-Balakot zone lies to the east of Main boundary fault. This zone constitutes late Proterozoic to Cenozoic sequence. This sequence is involved in the Muzaffarabad-Balakot southwestward overturned anticline. The late Proterozoic Dogra formation forms the core of the Muzaffarabad-Balakot anticline. The Dogra formation is unconformably overlain by the early Cambrian Muzaffarabd formation. The Ordovician (?) Yadgar formation disconformably overlies the Muzaffarabad formation. The Yadgar formation is unconformably overlain by the Paleocene-Eocene sequence which includes the Hangu Formation, Lockhart Formation, Patala Formation and Margala Hill Limestone. This was followed by the late Eocene Kuldana and Miocene Murree molasses. The most of the Paleocene to Miocene sequence along the overtuned limb of the Muzaffarabda-Balakot anticline is faulted.

The Garhi Habibullah-Abbottabad zone lies between the Main boundary fault and Garhi Habibullah fault. This zone is involved in the Garhi Habibullah syncline. The Cambrian Abbottabad group lies in the core and Hazara formation along the limbs of the anticline. In the Garhi Habibullah syncline, the late Proterozoic Hazara formation is unconformably overlain by the Cambrian Abbottabad group of rocks. The Jurassic sequence has been eroded from the core of the syncline due to later Himalayan uplift.

The Panjal zone lies between the Garhi Habibullah fault and Panjal fault. The Panjal zone includes the late Proterozoic to Triassic rocks which are involved in the Tarkot anticline and Doga syncline. In this zone the Carboniferous Chushal formation unconformably overlies the late Proterozoic Hazara formation and grades into the Permo-Triassic panjal formation. These rocks are metamorphosed up to lower green shcist facies metamorphism. The Mansehra zone lies west of Panjal fault. It includes the late Proterozoic Hazara and Tanol formations and intrusive Cambrian Mansehra granite. The grade of metamorphism varies from chlorite-grade in the south tostaurolite-grade in the north.

The Panjal and Mansehra zones are intruded by Permian mafic dikes aand sills of basalts and dolerites. These basalts and dolerites are fresh but at places show weak Himalayan metamorphic effects. The sedimentary, metamorphic and igneous rocks of these zones are classified by petrographic studies.

The rocks of these zones have been affected by multiple pre-Himalayan and Himalayan deformational events. Four deformational events have been recognized as D_1, D_2, D_3 and D_4 deformations. D_1 Hazran deformation is restricted to the late Proterozoic sequence. D_2 deformation produced a barrovian type metamorphism which produced lower-greenschist to amphibolite facies metamorphism in the Panjal and Mansehra zones. The effect of D_2 deformation is waek or absent in Garhi Habibullah and Muzaffarabad-Balakote zones. D_3 deformational event produced southeast-directed folds and thrusts in Mnsehra, Panjal and Garhi Habibullah zones. Whereas D_3 deformational event in the Muzaffarabad-Balakot zone produced southeast-directed folds and thrusts. The backsteepening and late extensional folding in all of the four zones occurred in the later phase of D3 deformation. However, the D_4 deformational event is related to the northwest plunging antiformal and synformal structures which are related to the formation of the Hazara-Kashmir syntaxis.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis.

Z/6. Zaheer, M.A., 1983. Catalogue of publications of Geoscientific Organisations by National Geodata Centre, Islamabad. Geological Survey of Pakistan, Information Release 208.

As the title indicates, this contribution is a directory of publications of geosciences organizations of Pakistan.
Key words: Geosciences publications.

Z/7. Zaheer, M.A. & Mirza, M.A., 1983. Geoscience Abstracts of Pakistan. Geological Survey of Pakistan, Information Release 207.

This is a list of abstracts related to various meetings and conferences in geological sciences, up to the year 1982.
Key words: Geoscience abstracts.

Z/8. Zahid, M. & Moon, C.J., 1998. Genesis of stratabound scheelite mineralisation Chitral, Northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 222-223.

Tungsten mineralisation lies within the Asian plate approximately 50-km to the north-west of Main Karakoram Thrust, which marks the suture zone between the Kohistan complex (Northern Pakistan) an Asian plate. Arkari Formation hosts the stratabound tungsten mineralisation at Miniki Gol, Chitral. This Formation is dominantly composed of garnet mica schist, phyllite, calc-silicate quartzite, marble and tourmalinite. Tungsten mineralisation is mainly represented by scheelite in the study are. Scheelite has been found in various rock types but is mainly concentrated in calc-silicate quartzite and subordinate tourmalinite. It occurs as discontinuous patches, stringers and conformable small veins within calc-silicate quartzite and thus can be classed as stratabound type.
Miniki Gol area has undergone at least two phases of deformation and metamorphism which are related to continent-arc collisions during the Cretaceous and Eocene respectively. The Miniki Gol metasediments are intruded by leucogranites emplaced after the culmination of amphibolite facies metamorphism. This felsic intrusion seem to be contemporaneous with the second phase of deformation.
Both the continuity and distribution of scheelite mineralisation appear to be influenced by the internal structure in the calc-silicate quartzite and tourmalinite. Scheelite in these rocks has partitioned along both overprint penetrative foliation and crenulation foliation. The concentration of some scheelite grains in hinges of the kink folds suggests that these foliation planes probably have acted as loci for the epigenetic mineralising fluids. The presence of scheelite grains within the cross-cutting quartz veins also suggests a post-granitic enrichment of the tungsten mineralisation.
The occurrence of calcic-amphibole (hornblende-actinolite), clinozoisite, titanite, calcite, anorthite, grossular garnet, diopside and scheelite fairly coordinates with the skarn mineral assemblage. Except for diopside and grossular garnet, these mineral compositions appear to show a consistent and common trend through out the deposits. This also establishes a genetic relationship between scheelite mineralisation and Miniki Gol leucogranite.
The high concentration of Zr, Hf, Be, Th, U, Ga, Nb, Y, Sn and W in scheelite-bearing calc-silicate quartzite compared to the unmineralised calc-silicate quartzite, psammite and schist implies a hydrothermal activity at the Miniki Gol area. Moreover, the consistency of the fluid inclusions both within leucogranite and calc-silicate rock also signify a genetic link between the scheelite mineralisation and the possible post-magmatic hydrothermal fluids.
Key words: Scheelite mineralization, economic geology, stratabound deposits, metapelites, Chitral.

Z/9. Zahid, M. & Moon, C.J., 1999a. P-T estimates of the calc-silicate rocks and the associated scheelite mineralization from the Miniki Gol, Chitral, N. Pakistan. Geological Bulletin, University of Peshawar, 32, 1-11.

Co-existing calcic-amphibole and plagioclase have been used to obtain pressure-temperature estimates from the calc-silicate rocks at Miniki Gol, Chitral, N.Pakistan. The Miniki Go1 calc-silicate rocks are located within the Hindu Kush range, approximately 50 km to the northwest of the Northern suture zone. Jurassic Arkari Formation hosts the calc-silicate rock, composed of clinozoisite, quartz, calcicamphibole, plagioclase, chlorite, biotite, calcite, sphene, garnet and scheelite.
A pair of coexisting ferro-tschermakitic hornblende and anorthite from scheelite bearing calc-silicate quartzite and a pair of andesine and magnesio-hornblende from barren calc-silicate quartzite were selected for P-T estimates. These pairs have apparently formed under equilibrium conditions. The tschermakitic hornblende anorthite pair yields a temperature range of 600-650^{0}C whereas the andesine and magnesio-hornblende pair

gives a temperature range between 530 ± 20^{0}C and 490 ± 20^{0}C. These temperatures are compatible with those of the upper amphibolite facies and greenschist facies metamorphism, respectively.
A general agreement was also observed when these estimates were checked with the criteria described for the correlation of temperature with increase in TiO, Na_20 and Al_2O_3, from actinolite to tschermakite. The chemistry of the tschermakitic amphibole indicates that the calc-silicate rock has formed at a pressure below 5 kbar. Keeping in view the variation of chemical composition ($A1_2O_3$, content) in calcic-amphibole associated with scheelite grains, it can be suggested that scheelite crystallised in a temperature range of 550^{0}C-400^{0}C.
Key words: Geothermobarometry, calc-silicates, scheelite mineralization, Chitral, Hindukush.

Z/10. Zahid, M. & Moon, C.J., 1999b. Genesis of tourmalinite from Chitral, Northern Pakistan. Geological Bulletin, University of Peshawar 32, 77-87.

Miniki Gol scheelite-bearing tourmalinite occurs within the Jurassic Arkari Formation. The Arkari Formation is located near the Pak-Afghan border within the Eastern Hindu Kush and is composed of garnet mica schist, phyllite, marble, mica quartzite, calc-silicate quartzite and subordinate toumalinite. The extension of tourmalinite is very limited and has been identified at three locations within the mica schist. Tourmalinite is dominantly composed of tourmaline, spessartine-rich garnet, quartz and scheelite. Tourmaline reaches up to 80% by volume in some tourmalinites. The chemical composition of tourmaline and garnet of the tourmalinite fairly corresponds with those of the nearby exposed leucogranite. The values of K,O, MnO, Zn, Rb and Ba of Miniki Go1 tourmalinite, are not markedly different from the associated schist and thus cannot be considered as siliceous chemical precipitates (exhalites). The limited extension of the tourmalinite is also inconsistent with the occurrence of exhalites. The lack of Sb, Hg, Ag, F and P in the tourmalinite also rules out the possibility of the exhalative activity in the study area. A linear relationship between LREE and elements of obvious igneous origin such as Zr, Hf and Be in the tourmalinite indicates a post-magmatic metasomatic activity. The Miniki Go1 leucogranite can be considered as potential source for the extreme enrichment of boron in the tourmalinite.
Key words: Tourmaline, scheelite, metasomatism, Chitral, Hindukush.

Z/11. Zaka, K.J., Bajwa, N.A. & Pervaiz, K., 1998. Landslide hazard zonation in the Hindukush Mountains at Golen Gol hydropower project, Chitral-A terrain evaluation approach. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.224.

Mitigation of disasters can be successful only when detailed knowledge is obtained about the expected frequency, character and magnitude of natural phenomena which may cause disaster in an area. The zonation of hazard must be the basis for any hazard mitigation project. To map such zones, a terrain classification map (TCM) has been prepared assuming slope as basic element. A land use map (LUM) was prepared using aerial photographs. A combination of TCM and LUM provides fair assessment of slope, vegetation, geology /structure and land use. Five hazard prone zones have been identified i.e. old stable landslides, old active landslides, recently active landslides and potential land slide zones. The interpretation of TCM, lineament map and engineering geological map leads to the conclusion that the area of thrusts and ridges are more prone to land sliding.
Key words: Landslide, hazard, hydropower, Hindukush.

Z/12. Zaka, K.J., Baloch, I.H. & Chaudhry, M.N., 1997. Provenance, alkali, aggregate reaction (A.A.R) and inservice behaviour of NW Himalayan gravels and sands in cement concrete at Terbala and Warsak Dams Pakistan. Geological Bulletin, Punjab University 31 & 32, 53-68.

For further information, consult the following summarized account of this paper.
Key words: Alkali aggregate, gravels, sands, cement concrete, Indus.

Z/13. Zaka, K.J. & Chaudhry, M.N., 1995. Provenance, alkali, aggregate reaction (A.A.R) and inservice behaviour of NW Himalayan gravels and sands in cement concrete at Terbala and Warsak Dams Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The NW Himalaya in Pakistan from which the gravel and sand of lndus River and its major tributaries are derived is geologically very complex. The mountain chains comprising this area have been formed by India Eurasia collision initiating at ca 65 m.y. with the Kohistan-Ladakh Island Arc trapped in between. The Indian plate at the leading edge is composed of Higher Himalayan S-type granitoids, migmatites and a sequence of high grade calc-pelites, marbles, pelites and psammites with layers of amphibolites. Granitoid, migmatite, carbonate, amphibolite and hard schists derived from these blocks are innocuous. Extensive mylonites have developed along Main Central Thrust, lndus Suture Zone and Thakot Fault and rarely within the Higher Himalayan crystallines (HHC). Quartz rich clasts of mylonites derived from these zones contain highly strained quartz with anomalous optics and are potentially deleterious.

The Lesser Himalaya to the south of the Higher Himalayan Block is composed of a northern metamorphic-igneous zone comprised predominantly of porphyritic S-type corderite granitoids, pelites and psammites. The southern sedimentary zone is comprised of pelites and psammites and a sequence of unmetamorphosed shelf carbonates with minor sandstone and shale horizons. The granitoid, hard schist and medium to high-grade psammites of metamorphic zone are innocuous. Slates, phyllites and graywackes in lower greenschist facies are potentially deleterious. Carbonate and sandstone clasts from the sedimentary part are innocuous. However chert clasts from this zone are potentially deleterious. The Balakot Mylonite Zone (B.M.Z) and Oghi Shear Zone (O.S.Z) yield deleterious strained quartz rich clasts. Microfractured quartz clasts derived from Hazara slate and Tanawal Formation of pelite psammite character from Lesser Himalaya are also potentially deleterious since they contain cryptocrystalline quartz along fracture cleavage developed during the second major deformation phase. The Kohistan Island Arc is composed of high grade amphibolites, acid to intermediate volcanics and I-type granitoids ranging in composition from granite to diorite and minor chert, volcanogenic arenites, carbonates, pelites and marl. The Kohistan terrain yields slightly reconstituted acid to intermediate merro to cryptocrystalline volcanics, pyroclasts and volcanogenic chertlchalcedony and arenites metamorphosed to a very low grade. These are again potentially deleterious. I-type granitoids and amphibolites are innocuous.

A gabbro-norite batholith also occurs in this terrain. The huge batholith variously interpreted as having been formed under a spreading center (Ghazanfar et.al. 1991), as a core batholith to the Kohistan Island Arc (Jan, 1980) or formed due to rifling of a mature arc or under a back arc spreading center (Khan et.al. 1992) is composed of about 95% gabbronorite, 1% ultramafics and 3% diorites and tonalites. The clasts derived from this source are innocuous.

The Kohistan Arc is bounded by two suture zones the northern of which is known as the Main Karakoram Thrust (MKT) while the southern branch is known as the lndus suture zone or the Main Mantle Thrust (MMT). The suture is composed of pillow lavas, peridotite and dunite cumulates, harzburgite tectonites, bedded cherts, volcanogenic chalcedonic cherts and flysch. The two suture zones contribute only small quantities of deleterious clasts derived from beddd/ribbon chert and other flyschoid sediments. The Karakoram Plate to the north of MKT is composed of a basement S-type granitoid complex over lain by high grade pelite, psammites, marbles and calc-pelites. This in turn is overlain by a sequence of slates and low grade carbonates. Only small quantities of potentially deleterious volcanics and low grade meta-argillites are contributed by this terrain.

The sand and gravel derived from this complex terrain has so far exhibited excellent physical characteristics. But these have shown alarming petrographic and chemical behaviour in concrete. A controversy has therefore continued over the past one decade as to the actual causes of deleterious deterioration in parts of already placed concrete.

In Tarbela and Warsak Dams natural sand and gravel from the river bed of Indus and Kabul were used respectively. In case of Terbala the coarse aggregates is composed on the average of amphibolitic/foliated diorite 27.6%, granodiorite/granite 16.1%, greywacke group 13.7%, quartzite/micaceous quartzite 13.0%, schist/subschist 7.4%, acid to intermediate volcanics 6.8%, phyllite 5.5%, carbonates 4.2%, garnet amphibolite 2.4%, basic volcanics 2.2%, diabase 0.9% and chert 0.2%. The fine aggregates are composed of quartz/quartzite/miaceous quartzite 30.5%, granite/granodiorite 20.2%, amphibolite/foliated diorite 10.7%, feldspar 10.0%, micas 5.8%, greywacke group 5.3%, amphibole 4.6%, schist 4.0%, phyllite/slate 3.3%, iron ore 1.3%, epidote 1.3%, carbonates 1.2%, volcanics 0.6%, garnet 0.3%, sphene 0.3%, chert 0.2%, tourmaline 0.2%, apatite 0.1%, zircon 0.1%. These were considered non-deleterious and were used with ordinary portland cement having~ alkali level ranging from 0.9% to 1.03%. Although the exact composition of cement used for construction of Warsak Dam is not known yet the record of analysis available show that the total alkalies level ranged from 0.9% to 1.20%.

The aggregates used in construction of Tarbela Dam contain large amounts of slightly metamorphosed acid to intermediate volcanics, argillites, microfractured quartzites, greywacke and a little chert. Although these aggregates contain large quantities of potentially deleterious rock types yet they were presumably regarded safe either because their parent rocks had undergone metamorphism or on the grounds that they had large quantities of mildly reactive rock types and therefore, would not develop deleterious reaction. It was only after twelve years of completion that A.A.R was confirmed in concrete structures of the dam (Chaudhry and Zaka 1994).

Similar type of aggregates were used for the construction of Warsak Dam. The coarse aggregates are composed of schist 11.6%, phyllite/slate 8.8%, amphibolite/amphibole gneiss 23.0%, quartzite 20.9%, granite/granite gneiss 21.5%, microfractured and strained quartzite 7.8%, acid to intermediate volcanics with microcrystalline matter 2.6%, limestone 3.0%, chert 0.8%. The fine aggregates are composed of quartz 35.2%, amphibole 12.3%, plagioclase/albite 7.9%, amphibolite/amphibole gneiss 7.0%, orthoclase/microcline 6.4%, quartzite 5.2%, schist 3.5%, granite/granite gneiss 4.1%, phyllite/slate 2.0%, magnetite 1.3%, biotite 2.6%, strained quartz 3.5%, microfractured and strained quartz 2.7%, muscovite 1.0%, chlorite 0.6%, limonite 0.8%, garnet 0.5%, acid to intermediate volcanic with microcrystalline matter 1.1%, limestone 1.6%, sphene 0.2%, chert + microcrystalline quartz 0.5%, tourmaline Tr. Warsak Dam civil structures have undergone deterioration due to A.A.R especially the Power House installations. The rock types, which are directly responsible for deleterious reactions, are microfractured quartzite, phyllite/slate, and partially reconstituted merrocrystalline acid to intermediate metavolcanics and a little chert.
The aggregates were considered safe by earlier works on the grounds that the deleterious rock types like argillites, greywackes, quartzite and acid to intermediate volcanics had undergone metamorphism. We suggest that these rocks have been reconstituted in very low-grade metamorphic zone (Winkler, 1976) or prehnite-pumpellyite to lower greenschist facies. As such the reactive silica phases and phyllosilicates have not been reconstituted completely to innocuous mineral phases. We further suggest that such rocks are rendered innocuous only when metamorphosed to biotite grade on an equivalent reaction in greenschist facies. In phyllosilicate bearing rocks it is characterized by the transformation of illite to structurally well ordered micas or equivalent transformations.
The presumption that a large quantity of reactive rock types in Indus aggregate may render it innocuous is not proved. While Pessimum can be applied to gravel composed predominantly of one rock type (flint gravel of U.K. or France from London or Paris Basins) the same is difficult to extrapolate for polymit gravels with a variety of reactive rock types unless prolonged experimentation furnishes a justification. alkali, aggregate reaction (A.A.R) and inservice behaviour of NW Himalayan gravels and sands in cement concrete.
Key words: Alkali aggregate, gravels, sands, cement concrete, Indus.

Z/14. Zakir, S. & Shaheen, F., 2001. Monitoring of groundwater quality in Gadoon Amazai Industrial Estate, NWFP, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.48.

Industrial effluents are potential source of water pollution. The lack of in-plant control measures, discharge of untreated wastewater through open drainage system and the lack of implementation of existing regulation remain serious threats to the quality of surface and ground waters. The present study was carried out to evaluate the pollution load of ground water contamination in the Gadoon Amazai Industrial Estate (GAlE). A total of 21 samples were collected from GAlE during three months from five tube wells, one hand pump and one dug well and analysed for biological oxygen demand, chloride, electrical conductivity, nitrate-nitrogen, sulphate and sulphide. The overall result showed that the concentrations of all the parameters were within the permissible limits as recommended by World Health Organization (WHO). These industries are however, the potential sources of ground water pollution. Immediate implementation of on site control measures, treatment plants and awareness of the industrialists are suggested as futuristic measures forsaving the ground water from the expected industrial pollution.
Key words: Groundwater, pollution, Gadoon-Amazai, Swabi.

Z/15. Zaleha, M.J., 1997a. Fluvial and lacustrine palaeoenvironments of the Miocene Siwalik Group, Khaur area, northern Pakistan. Sedimentology 44, 349-368.

The Miocene Siwalik Group (upsection, the Chinji, Nagri, and Dhok Pathan Formations) in northern Pakistan records fluvial and lacustrine environments within the Himalayan foreland basin. Thick (5 m to tens of metres) sandstones are composed of channel bar and fill deposits of low-sinuousity (1·08–1·19), single-channel meandering and braided rivers which formed large, low-gradient sediment fans (or ‘megafans’). River flow was dominantly toward the south-east and likely perennial. Palaeohydraulic reconstructions indicate that Chinji and Dhok Pathan rivers were small relative to Nagri rivers. Bankfull channel depths of Chinji and Dhok Pathan rivers were generally ≤ 15 m, and up to 33 m for Nagri rivers. Widths of channel segments (including single channels of meandering rivers and individual channels around braid bars) were 320–710 m for Chinji rivers, 320–1050 m for Nagri rivers, and 270–340 m for Dhok Pathan rivers. Mean channel bed slopes were on the order of 0·000056–0·00011. Bankfull discharges of channel segments for Chinji and Dhok Pathan rivers were generally 700–800 m^3s^{-1}, with full river discharges possibly up to 2400 m^3s^{-1}. Bankfull discharges of channel segments for Nagri rivers were generally 1800–3500 m3s−1, with discharges of some larger channel segments possibly on the order of 9000–32 000 m^3s^{-1}. Full river discharges of some of the largest Nagri braided rivers may have been twice these values.

Thin (decimetres to a few metres) sandstones represent deposits of levees, crevasse channels and splays, floodplain channels, and large sheet floods. Laminated mudstones represent floodplain and lacustrine deposits. Lakes were both perennial and short-lived, and likely less than 10 m deep with maximum fetches on the order of a few tens of kilometres. Trace fossils and body fossils within all facies indicate the former existence of terrestrial vertebrates, molluscs (bivalves and gastropods), arthropods (including insects), worms, aquatic fauna (e.g. fish, turtles, crocodiles), trees, bushes, grasses, and aquatic flora. Palaeoenvironmental reconstructions are consistent with previous palaeoclimatic interpretations of monsoonal conditions.

Key words: Sedimentary deposits, fluvial, Siwaliks, Potwar.

Z/16. Zaleha, M.J., 1997b. Intra- and extra-basinal controls on fluvial deposition in the Miocene Indo-Gangetic foreland basin, northern Pakistan. Sedimentology 44, 369-390.

Key words: Deposition, foreland basin, Miocene, Siwaliks.

Z/17. Zaman, H., 1993. Geology, tectonics and paleomagnetism in northern Pakistan and the field program in Chitral. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad 7, 34-43.

Geology and tectonics of northern Pakistan are briefly described together with an overview of paleomagnetism in Ladakh and Chitral. Preliminary paleomagnetic results from the Cretaceous-Paleogene Red Beds of Chitral (collected by Zaman et al) are given in an appendix. The data suggest low latitude for Chitral area in Cretaceous – Paleogen time. It is also inferred that Chitral area was not originally a part of Eurasia.

Key words: Tectonics, Paleomagnetism, Chitral, Hindukush.

Z/18. Zaman, H., & Torii, M., 1995a. Preliminary result of paleomagnetism from the Cretaceous red beds of the eastern Hindu Kush, Chitral, Pakistan. Autumn Meeting. Geomagnetism Soc., Earth Planet. Space Science. (SGEPSS), Kyoto, Japan. Abst., 22–24.

For additional information, see Zaman and Torii, 1996a and 1996b.

Key words: Paleomagnetism, red beds, Chitral, Hindukush.

Z/19. Zaman, H. & Torii, M., 1995b. Preliminary results of paleomagnetism from the Cretaceous red beds of the eastern Hindukush, Chitral, Pakistan. In: Khadim, I.M. & Yoshida, M. (eds.), Rock Magnestism and Paleomagnetism. Recent Progress in Pakistan, Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad) 13, 137-147.

For additional information, see Zaman and Torii, 1996a and 1996b.

Key words: Paleomagnetism, red beds, Cretaceous, Chitral.

Z/20. Zaman, H., & Torii, M., 1996a. Paleomagnetic study of the Cretaceous red beds from the eastern Hindu Kush Range, northern Pakistan: Paleoreconstruction of the Kohistan–Karakoram composite unit before India–Asia collision. International Seminar on Paleomagnetic Studies in Himalaya–Karakoram collision belt. Geological Survey of Pakistan. Geoscience Labs. Extended Abstracts, 1-4

In order to study the tectonic displacement of the Kohistan-Karakoram region, we collected more than 350 paleomagnetic samples in two field trips from the Chitral district of northwestern Pakistan (35" 28' to 36" 16' N, 71" 44' to 72O 20' E). In the first phase of sampling Devonian to Cretaceous sedimentary, volcanic and plutonic rocks were sampled from the Kohistan and Karakoram terranes. In the second phase of samplings, mid-Cretaceous red beds were exclusively sampled from Drosh-Shishi area of Kohistan terrane. Here we report paleomagnetic results obtained from the mid-Cretaceous red beds of Drosh-Shishi and Buni areas.

On the basis of paleomagnetic results, thermal rather than alternating field demagnetization allowed the separation of multi-components magnetization. As shown in the Figure 1 (a, b, c), most of the samples (except

that of Northern Suture zone in Figure Id) revealed three components of magnetization. The most unstable A component was broken down between 200" and 500•‹C. In the geographic coordinates the site mean direction for the A component (D =15.0•‹, 1 = 54.2") is close to the present field direction of the sampling area, indicating a recent origin for this component An intermediate component (B) was separated from 300" to 660•‹C Tilt-corrected mean direction for the B component from all three formations gave a mean direction (D = 284 2", I = 1 0") with northwestward declination and very shallow positive inclination. The omnipresence of this partially overprinted remanence across the Northern Suture zone is probably related to the time of temperature enhancement after the India-Asia collision, indicating that thermochemical remanent magnetization is responsible for the acquisition of B component The direction obtained from the B component is nearly consistent with the previously reported characteristic direction (interpreted as a remagnetization) from the adjacent area (Klootwijk et a1 , 1994) The equatorial to low northern paleolatitude (-O.SON) fiom the B component is in good support to the Klootwijk et al. (1994) interpretation, that initial India-Asia contact was established at, or before the Cretaceous-Tertiary (KT) boundary at equatorial to low northern paleolatitudes.
Figure 1: Orthogonal projections and intensity plots of thermal demagnetization in the stratigraphic coordmates. Solid (open) symbols indicate projection onto the horizontal (vertical) plane. (a) Reshun Formation (b) Punt Formation (c) Drosh Formation (d) Northern Suture zone. The temperature range for the most stable characteristic remanent magnetization (0 is found to be variable 6om one locality to another, and is generally unblocked between 600" and 685•‹C. The mid-Cretaceous ChRM direction obtained from the C component is clearly divided into two separate groups. Group of sites fiom the Purit Formation gave a characteristic direction (D = 311.2", I = -4.4', k = 12.4, ag5 =17.8") with northwestward declination and very shallow negative inclination. Dual polarity, very high coercivity and unblocking temperatures, positive fold and conglomerate tests all satisfies the condition that the ChRM of the Purit Formation was acquired before folding, and most likely as a depositional rernanent magnetization. Comparison of mean declination fiom the Purit Formation group with the Cretaceous apparent polar wander paths (Besse and Courtillot, 1991) indicate a counterclockwise rotation of about 66" and 15" relative to Eurasia and India, respectively. The counterclockwise rotation is consistent with the regional structure of the Hindukush-Pamir-Karakoram syntaxial bend. The mean ChRM direction obtained fiom the Reshun and Drosh formations is, D = 79.1•‹, I = -4.7, k = 28.3, a95 = 12.8. Positive fold test, high unblocking temperature and relatively low coercivity suggests that the ChRM of Drosh Formation was acquired before folding, and most likely as a chemical remanent magnetization. In contrast to the Purit Formation, the northeastward mean declination fiom the Reshun and Drosh formations indicates that the sampling area experienced a clockwise rotation of about 62" and 113" with respect to Eurasia and India, respectively. This unusual clockwise rotation is not consistent with the regional superstructure, and is probably related to the local tectonic movement caused by the rotation of thrust sheets along the Northern Suture zone.
The paleolatitudes obtained fiom mean inclinations are 2.2"s and 2.3"s for the Purit and Reshun+Drosh formations, respectively. By comparing these paleoposition of the Kohistan-Karakorarn area with the present day latitude (-35"N), implying that over 3500 Ian of crustal shortening was taken place since mid-Cretaceous time, of which more than 90% postdated the India-Asia collision (Figure 2). The shortened crust was most likely consumed by continental underthrusting, intercontinental thrusting with internal deformation and lateral extrusion along major and minor faults (Molnar and Tapponier, 1975). About 3" paleolatitudinal difference between B and C components indicates that the study area was pushed northward about 300 krn from the time of red bed deposition to that of India-Asia collision (Figure 2). The displacement of the sampling area between two acquisition points is acceptable in the sense, that during the said period oceanic part of the subducting Indian Plate was pushing forward the Kohistan-Karakoram terranes towards north. The ChRM directions fiom the Reshun and Drosh formations are nearly consistent, which probably indicate that these two formations could be placed on the same platform, at the north side of the suture zone. In this case a faulted boundary between the Purit and Drosh formations cannot be ruled out, most likely under the cover of Shishi River. The mid-Cretaceous inclination values Figure 2: Comparison of the palcolatihdes oMainod from tbe intermediate B and C components with the Cretaceous palageographic reconstruction of Asia (redrawn from Chen ct al., 1993). It is indicated that more than 3500 Ian of crustal shortening was taken place after the ChRM acquisition at equatorial palalatrtudc, and more than 90% of 11 postdated the acquisition of B component @robably related to India-Asla coll~sion). obtained across the Northern Suture zone are almost identical, which indicates that suturing has been completed at the time of ChRM acquisition. This is in good agreement with the geochronological results &om North Pakistan, which date the age of suturing at 102-85 Ma (Treloar et al., 1989).
Key words: Paleomagnetism, red beds, Cretaceous, Chitral.

Z/21. Zaman, H. & Torii, M., 1996b. Paleoposition of the Kohistan-Karkoram composite unit: A paleomagnetic study of the Cretaceous red beds from the eastern Hindukush Range of Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 175-176.

In order to study the tectonic deformation of he Eastern Hindukush region, we collected paleomagnetic samples within Chitral district of northwestern Pakistan (35° 28´ to 36° 16´, 71° 44´ to 72° 20´). During two field trips, more than 350 hand samples of Devonian to Cretaceous sedimentary, volcanic and plutonic rocks were collected at 20 localities. Here we report paleomagnetic results obtained form the Mid-Cretaceous red beds of Drosh-Shishi and Buni areas (Purit and Drosh Formations from Drosh-Shishi area and Reshun Formation from Buni area: by Pudsey et al., 1985).
The rock magnetic parameters indicate that magnetic minerals are variable from one formation to another. The dominant magnetic carrier identified in the samples of the Purit Formation is a high temperature hematite. In the samples of the Drosh Formation two kinds of magnetic minerals are present, that is a dominant hematite and subordinate magnetite. The ratios of magnetic minerals are changing in the sample of Reshun Formation, where hematite and goethite are dominant in the red mudstone and pebble conglomerates respectively. On the basis of paleomagnetic results, thermal demagnetization allowed the separation of multi-components magnetization. Most of the samples revealed three components of magnetization (except two sites from the Northern Suture). A recent field component (A) was removed between 200° and 500°C. An intermediate thermal stability component (B) was separated from 300° to 660°C. The temperature range for the characteristic remnant magnetization (ChRM) component (C) is found to be variable from one locality to another, and is generally unblocked between 600° and 685°C. In the geographic coordinates the site mean direction for component A (D=15.0°. I=54.2°) is nearly similar to the present field direction of the sampling area, indicating a recent origin for this component. Tilt corrected intermediate component (B) from all three formation gave a mean direction (D=284.2°, I=1.0°, k=7.9, a95=18.3°) with northwestward declination and very shallow positive inclination. A uniform presence of this secondary magnetization across Northern Suture indicates that it was probably acquired at the time of India-Asia collision. The direction obtained from component B is nearly consistent with the previously reported characteristic direction (interpreted as a secondary remagnetization) from the adjacent area (Klootwijk et al., 1994). The Mid-Cretaceous ChRM direction obtained from C component (thirteen sites) is clearly divided in to two separate groups. Group of sites from the Purit Formation gave a characteristic direction (D=311.2°, I=4.4°, k=12.4, a95=17.8°) with northwestward declination and very shallow negative inclination. The corresponding pole for the Purit Formation is located at 31°S, 133°E. The mean ChRM direction obtained from the Reshun and Drosh Formations is, D=79.1°, I=4.7, k=28.3, a95=2.8°, with corresponding pole position at 7°N, 169°E. In both cases the positive fold taste indicates that the ChRM component was acquired before folding, and is most likely the primary magnetization.
Comparison of mean declination from the Purit Formation group with the Cretaceous apparent polar wander paths (Besse and Courtillot, 1991) indicate a counterclockwise rotation (Kohistan block) of about 66°and 15° relative to Eurasia and India, respectively. The counterclockwise rotation is consistent with the regional structure of the Hindukush-Pamir-Karakoram syntaxial bend. In contrast the northeastward mean declination from the Reshun and Drosh Formations indicate that the sampling area experienced a clockwise rotation of about 62° and 113° with respect to Eurasia and India, respectively. This unusual clockwise rotation is probably related to the local tectonic movement caused by the rotation of thrust sheets along the Northern Suture Zone. The paleolatitudes obtained from mean inclinations are 2.2 and 2.3°S for the Purit Formation and Reshun + Drosh Formations, respectively. By comparing this paleoposition of the Kohistan-Karakoram composite unit with the present day latitude (~35°N), implying that over 3500 km of crustal shortening was taken place since Mid-Cretaceous time, of which more than 90% postdate the India-Asia collision. The ChRM directions from the Reshun and Drosh Formations are nearly consistent, which probably indicate that these two formations could be placed on the same platform, at the north side of the suture zone. In this case a faulted boundary between the Purit and Drosh Formations cannot be ruled out, most likely under the cover of Shishi River. The Mid-Cretaceous inclination values obtained across the Northern Suture are almost identical, which indicates that suturing has been completed (or near to completion) at the time of ChRM acquisition. This is good agreement with the geochronological results from North Pakistan, which date the age of suturing at 102-85 Ma (Treloar et al., 1989).
Key words: Paleomagnetism, Paleoposition, Kohistan, Chitral, Hindukush.

Z/22. Zaman, H. & Torii, M., 1996c. Rock magnetism of the mid-Cretaceous red beds from the Kohistan and Karakoram terranes, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 102-105.

We report rock magnetic results obtained from the mid-Cretaceous red beds samples, collected from the eastern Hindukush ranges of northern Pakistan. Most of the rock magnetic samples were collected from the. Purit, Drosh and Reshun formations, while two localities were sampled from the Northern Suture Zone. The Reshun

Formation of the Karakoram Plate side is a group of rocks including polymict pebble and cobble conglomerates, red calcareous shale and pale gray micritic limestone lies below the Reshun Fault and above Chitral slate or Darkot Group of sediments. On the basis petrographic work (Pudsey, 1986), it is suggested that fluvial sediments of the Reshun Formation was largely derived from the volcanic arc. The red beds of Drosh-Shishi area is lying just south of the Northern Suture zone within the Kohistan terrane, and is divided in to three different rock units. In case of Purit Formation, red calcareous shale with abundant calcite veins is the most dominant rock type, while conglomerates and sandstone constitutes about one third of the formation in the lower half overlying the Purit Formation is the Drosh Formation, which is a sequence of thickly-bedded andesitic volcanics. Some thin red calcareous shales are interbedded with the lava flows. The overlying unit of Northern Suture zone consists mainly of dark-gray limestone interbedded with black phylite and black calcareous shale (Pudsey, 1986).

Rock magnetic properties indicates that magnetic minerals are variable from one formation to another. From thermomagnetic analysis and low temperature measurements it is determined that hematite is the dominant magnetic carrier in the samples of Purit Formation (Figure lc, d). Furthermore very high coercivity and unblocking temperature indicates that the hematite grains are probably detrital in origin, which in turn is the carrier of characteristic remanent magnetization (ChRM) in the red beds of Purit Formation. From the paleomagnetic components studies it is fbrther indicated that some low thermal stability hematite is also present as a secondary magnetic mineral by comparing with the paleomagnetic results, it is suggested that low temperature hematite is responsible for the acquisition of B component (secondary remagnetization), and is probably related to the time of temperature enhancement after the India-Asia collision, indicating that thennochemical processes are responsible for the production of secondary magnetic minerals. This idea can fairly be compared with the temperature increase above 300•‹C deduced from zircon resetting at 55-68 Ma from the adjacent area (Zeitler, 1985). The ratio of magnetic minerals are changing in the samples of Reshun Formation, where hematite and goethite are dominant in the red mudstones and pebble conlomerates, respectively (Figure la, b). This probably indicate that the source and depositional environment of the existing magnetic minerals were different for the red mudstones and conglomerate beds.

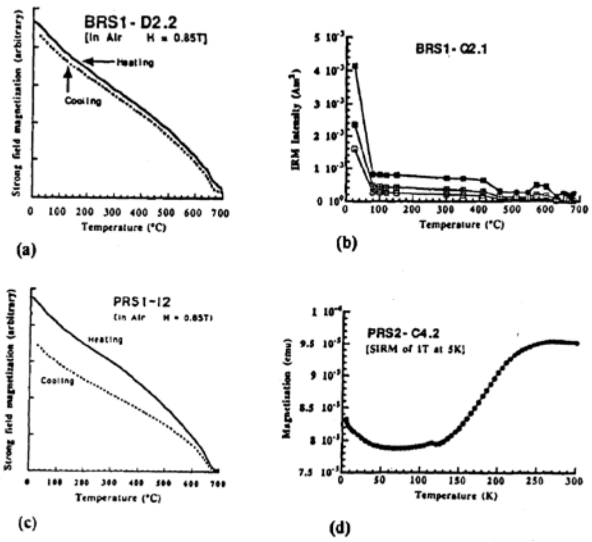

Figure 1: Results of the rock magnetic study for the samples of Reshun (BRS 1.D2.2 and BRS 142-1) and Punt (PRSI-I2 and PRS~:CJ-~) formations (a and c) Strong field thennomagnetic analysis in air (b) Thermal demagnetuauon of a three components IRM produced by magnetizing the sample in a field of 1.3, 0.4 and 0.12 T success~vcly along three Werent axes. (d) SIRM of 1 Tesla was imparted at 5 K and then heated up to 300 k

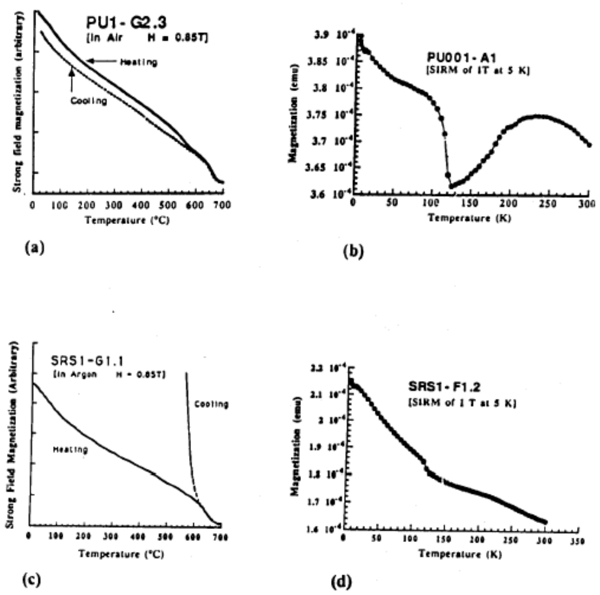

Figure 2: Results of the rock magnetic study for the samples of Drosh Formation (PUl-G2.3 and PUO I-Al),an Northern Suture Zone (SRSl-Gl.1 and SRSl-Fl.2) (a and c) Strong field thermomagnetic analysis in air an argon. respxtncly (band d) SIRM of 1 Tesla was imparted at 5 K and then heated up to 300 K.

In the samples of the Drosh Formation two kinds of magnetic minerals are present, that is a dominant hematite and subordinate magnetite (Figure 2a, b). As evident from the field observation, the red beds of Drosh Formation is thinly interbedded with the andesitic volcanics Here the source of red beds deposition is probably shared by the volcanic ashes and other fine sediments from the surrounding volcanic rocks, which could result in the possible presence of very fine gamed magnetic minerals (Superparamagnetic and Single Domain magnetite grains). As described by Turner (198 1) that in some cases the original sediments may have been rich in magnetite, but after progressive diagenesis (including oxidation of magnetite) very fine magnetite could be replaced by hematite It is therefore predicted that the hematite of Drosh Formation was formed by martitization or hydrothermal alterations of the preexisting detrital magnetite, while the subordinate magnetite was probably recrystalized as a result of temperature enhancement after the India-Asia collision. By comparing with the plaeomagnetic results of the same samples it is suggested that hematite is the camer of ChRM, and secondary remagnetization component (B) is carried by magnetite. The magnetic mineralogy in the samples of Northern Suture Zone is shared by hematite, magnetite and probably iron sulfides. On the basis of rock magnetic characteristics the dominant magnetic carrier is the low coercivity and low temperature hematite (Figure 2c).

From low temperature measurements the verway transition of magnetite is very clearly determined, while the presence of hematite is very poorly shown (Figure 2d). This behaviour around the Morin transition zone of hematite (the decreasing change in the remanence with increasing temperature) may reflects the presence of the superparamagnetic grains, which unblocked near the room temperature (Hunt et al., 1995). Unstability of the magnetic minerals in the samples of Northern Suture zone is also indicated from the paleornagnetic results, where the direction of the ChRM is identical with the present Earth's field direction in the sampling area

Key words: Paleomagnetism, Paleoposition, Kohistan, Chitral, Hindukush

Z/23. Zaman, H. & Torii, M., 1996d. Rock magnetism of the mid-Cretaceous red beds from the northwestern margin of Kohistan island arc, northern Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad) 15, 207-232.

We report rock magnetic results obtained from the mid-Cretaceous red beds samples, collected tiom the northern margin of Kohistan island arc, northern Pakistan. Rock magnetic parameters indicates that magnetic minerals are variable from one formation to another. Detrital hematite is the dominant magnetic carrier in the samples of the Purit Formation, while low stability hematite is probably the carrier of secondary magnetization. In the samples of the bosh Formation two kinds of magnetic minerals are present, that is a dominant hematite and subordinate magnetite. Hematite here is probably formed by the in-situ oxidation of pre-existing detrital magnetite, suggesting the magnetization origin as a chemical. The magnetic mineralogy in the samples of

Northern Suture Zone is shared by hematite, magnetite and probably iron sulfides. Unstability of the remanence in the samples of Northern Suture Zone is probably due to the presence of superparamagnetic hematite grains.
Key words: Paleomagnetism, Paleoposition, Kohistan,

Z/24. Zaman, H. & Torii, M., 1997. Rock magnetism of the mid-Cretaceous red beds from Kohistan and Karakoram blocks, northern Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (eds.), Paleomagnetism of Collision Belts. Geoscience Laboratory, GSP, Islamabad, 13-33.

Rock magnetic studies were carried out in order to identify the remanence canying minerals in the mid-Cretaceous red bed rocks from the Eastern Hindukush mountains, northern Pakistan. Rock magnetic properties indicate that remanence canying minerals are variable from one formation to another. In the samples of the Purit Formation detrital specular hematite is the dominant carrier of characteristic remanent magnetization (ChRM), while low stability pigmentary hematite is responsible for the acquisition of secondaty magnetization. Two kinds of magnetic minerals are present in the samples of the Bosh Formation, i.e., a dominant hematite and a subordinate magnetite. This hematite was probably formed by the in situ oxidation of pre-existing detrital magnetite, suggesting the ChRM origin as a chemical, while magnetite is the alteration product attributed to India-Asia collision. The magnetic mineralogy in the samples of the Northern Suture Zone @SZ) is shared by hematite, magnetite and probably iron sulfides. Recently acquired ChRM in the samples of NSZ is probably due to the presence of ultrafie hematite grains. The ratio of magnetic minerals are changing in the samples of the Reshun Formation, where detrital hematite is dominant in the red mudstone and goethite in pebble sapdstone. Here detrital and pigmentary hematite are responsible for the acquisition of ChRM and intermediate component of magnetization, respectively. In some samples, the presence of magnetite is also indicated by the isothermal remanent magnetization methods.
Key words: Paleomagnetism, collision belts, Kohistan, Chitral, Hindukush.

Z/25. Zaman, H. & Torii, M., 1999a. Palaeomagnetic study of Cretaceous red beds from the eastern Hinudkush ranges, northern Pakistan: Palaeoreconstruction of the Kohistan-Karakoram composite unite before India-Asia collision. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 1-4.

For details, consult Zaman and Torii, 1996b and 1999b.
Key words: Paleomagnetism, red beds, Kohistan, Chitral, Hindukush.

Z/26. Zaman, H. & Torii, M., 1999b. Palaeomagnetic study of Cretaceous red beds from the eastern Hinudkush ranges, northern Pakistan: Palaeoreconstruction of the Kohistan-Karakoram composite unit before the India-Asia collision. Geophysical Journal International 136, 719-738.

We report palaeomagnetic results obtained from Cretaceous red bed sample, collected from the eastern Hindukush mountains, northern Pakistan. Rock magnetic studies revealed specular haematite as the dominant remanence carrier, while pigmentary haematite, magnetic and geothite are reponsible for the accquisition of secondary magnetizations. Thermal treatment generally revealed three components of manetizations. The most unstable component (A) was removed between 200 ºC and 500 ºC, which corresponds to the local present field direction. The intermediate component (B) was generally separated between 200 ºC and 600 ºC. The ominipresence of this complex secondary component across the Northern Suture Zone suggests that movement of chemically active orogenic fluids at, or slightly before, the time of the Inida-Asia collision was probably responsible for the authigenic remagnetization processes. The characteristic component (C) was generally unblocked between 600 0C and 685 0C. The characteristic directions from 12 sites fall into two groups. The sites from the Purit Formation give a tilt-corrected mean direction of D=311.20 I=4.40 , K=12.4, œ95=17.80 , indicating a counter-clockwise rotation of about 660 and 150 relative to Eurasia and India, respectively. The tilt-corrected mean direction for the Reshun and Drosh formation is D=263.00 , I=2.20 , K=52.7, œ95 =10.60 which indicates that the sampling area experienced a counter-clockwise rotation of about 1140 and 630 with respect to Eurasia and India, respectively. In both cases the palaeomagnetic rotation is consistent with the regional superstructure of the Hindukush-Pamir-Karakoram syntaxial bend. The difference in rotation between these two groups is probably due to local tectonic movement caused by the net rotation of thrust sheets along the Northern

Suture Zone. The palaeolatitudes calculated for Purit and Reshun+Drosh formations are 2.20S and 1.10N, respectively. This indicates that about 4000km of convergence has taken place since the mid-Cretaceous, of which about 90 per cent post-dates the India-Asia collision. The Late Cretaceous, inclination values across the Northern Suture Zone are almost identical, which indicates that suturing had been completed at the time of ChRM acquisition.
Key words: Paleomagnetism, Kohistan, Chitral, Hindukush

Z/27. Zaman, H., Torii, M., Yoshida, M. & Karim, T., 1994. Preliminary paleomagnetic results from the Cretaceous–Paleogene red beds of Chitral area, northern Pakistan. 1994, Spring Meetimgg. Geomagnetism Soc., Earth and Planet. Space Science, (SGEPSS), Abstract volume.

For more information, consult Zaman and Torii, 1996b.
Key words: Paleomagnetism, red beds, Cretaceous-Paleogene, Chitral, Hindukush

Z/28. Zaman, H., Yoshida, M., Khadim, I.M., Ahmad, M.N. & Akram, H., 1998. Paleomagnetism of the Himalaya–Karakoram belt and surrounding terranes since Jurassic: Implications for three phase collision history. In: Gondwana's Paleomagnetism. Geological Society of India, Special Publication.

Key words: Paleomagnetism, Jurassic-Tertiary, Karakoram, Himalaya.

Z/29. Zaman, M., 1967-68. The geology of the Kiwai-Paras Area, Lower Kaghan Valley, (District Hazara), West Pakistan. M.Sc. Thesis, Punjab University, Lahore, 94p.

Key words: Geology, Kaghan, Mansehra.

Z/30. Zaman, M., 1974. Geology of the raw material available in North West Frontier Province. M.Sc. Thesis, Peshawar University, 66p.

Key words: Raw material, geology, NWFP.

Z/31. Zaman, M.Q., 1961. Exploration and development of petroleum in Pakistan. Natural Resources 1(1), 33-41.

Key words: Hydrocarbon, exploration.

Z/32. Zaman, R., 1988-90. Geology and structure of Kotli-Nikial-Khuiratta area Kotli A.J.K. with special emphasis on Himalayan Frontal Thrust and related structures. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 115p.

Geological and structural mapping of Kotili-Nikial-Khuiratta area of about 300 square km was carried on 1:50,000 scale of toposheat No's 43 K/2, 43 K/3, 43 G/11 and 43 G/15 of survey of Pakistan. The lithostratigraphic units described range in age from Pre-Cambrian to Pleistocene and consist mainly of sedimentary rocks. The Pre-Cambrian rock formation is Dogra Slate and Cambrian rock unit is Sirban Formation.
In this area apart from Lower Cambrian, all the formations of Paleozoic and Mesozoic are missing. Either they were not deposited or were weathered to form Bauxite/Fireclay representing an unconformity of a big gap. In the Tertiary period, Patala Formation, Margala Hill Limestone, Murree Formation and rocks of Siwalik Group were deposited. Section measurements were done to establish the stratigraphy. The rocks are folded and faulted comprising the major and minor structures of the area. The major folds of the area are khuiratta-Kohali anticline (11ρρ/325ρρ), Devigarh-Palana anticline (04ρρ/313ρ), Tattapani-Karela anticline (6ρρ/116ρρ) and Khad-Bahni syncline (6ρρ/228ρρ). The major fault is the Himalayan Frontal Thrust with minor thrust like Gala Thrust and Khad Thrust. Deformational events and stereographic projection of the area have been interpreted. The tectonic setup has been also discussed. About eighty five rock samples were taken from the field and carried back to the

laboratory for petrographic studies. In the field of economic geology, a number of deposits including Fireclay, Bauxite, Coal, Limestone, Chalk and Dolomite are of economic interst.
Key words: Geology, structure, Himalayan Frontal Thrust, Azad Kashmir.

Z/33. Zaman, R.S. & Saeed, U., 1979. Development of land and groundwater resources in Kurram Gambila Road, District Bannu. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Land resources, groundwater, Bannu.

Z/34. Zaman, S. & Hashim, M., 1983. The structures, stratigraphy and statistical studies of Siwalik group of area north of Taba Nala, Mianwali District, Punjab. M.Sc. Thesis, University of Peshawar, 111p.

Key words: Structure, stratigraphy, Siwaliks, Mianwali.

Z/35. Zaman, W. & Rehman, N., 1990. Geological investigations of Bhal Syedon (Fateh Jhang) Well No. 2 with special reference to drill cutting analysis. M.Sc. Thesis, University of Peshawar, 144p.

Key words: Geology, well log, hydrocarbon, Fatehjhang, Attock.

Z/36. Zanchi, A., 1992. Structural Evolution of the Karakoram Sedimentary cover: preliminary data. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 101.

Preliminary field structural analyses and reconnaissance mapping of the north Karakorum sedimentary cover has been carried out in the Chapursan and Shimshal valleys north of the axial batholith, on the basis of previous stratigraphic reconstructions (Gaetani et al., 1990).
In the Chapursan Valley the structure of the sedimentary cover consists of a complex and polyphasic stack of embricated and locally verticalized Permian to Jurassic thrust sheets, also including the discordant Tupop conglomerates, Cretaceous in age. The oldest deformational event is outlined by an E-W striking belt composed of verticalized and tectonized sediments belonging to the Permian-Jurassic sequences, overlain by the Cretaceous Tupop Formation with a sharp stratigraphical unconformity. Corn p ressional events subsequent to Tupop deposition produced the the main stack of thrust sheets, including strongly deformed and folded slices of Tupop. In the Chapursan Valley slip vectors along thrust planes and fold axes indicate a northward direction of transport, whereas NW-SE trending fold axes due to northeastward transport have been mainly observed in the Shimshal valley. The north vergent structure is widely crossed by successive breakback thrusting, evident along the northern side of the Chapursan valley (Northern fault of Gaetani et al., 1990), and along the contact between the sedimentary cover and the axial batholith outcropping in the Yaskuk Glacier area.
The last recognized tectonic phase is the activation of an important set of E-W sinistral strike-slip faults, causing further steepening of previously embricated thrust sheets. These faults may be interpreted as a consequence of a NW-SE directed simple-shear, probably due to deformation along major NW-SE dextral strike-slip faults, as the Misgar dextral strike-slip fault. The sedimentary cover of the north Karakoram is deformed under anchimetamorphic conditions in the Chapursan valley, while sericite to muscovite phyllites of low-grade outcrop in the Shimshal valley. Near the Shimshal Pass andalusite and biotite have been detected in phyllites at the contact aureole of large previously unknown granitic bodies. Cataclasis is mostly evident along thrust planes and strike-slip faults, thus showing brittle conditions of deformation.
Key words: Sedimentary cover, stratigraphy, petrology, structure, Hunza, Gilgit, Karakoram.

Z/37. Zanchi, A., 1992. Structural history of the north Karakorum terran in the upper Hunza valley, Pakistan. In: Zheng, d., Zhang, Q. & Pan, Y. (eds.), Proceedings of international symposium on the Karakorum and Kunlun mountains. China Meteorological Press, Beijing, 143-151.

The sedimentary cover of the north Karakorum terrain is composewd of three msain structural units: Gujhal, Sost and Misgar Units characteriuzed by different stratigraphic and tectonic evolution.Fold and thrust surfaces

generally trend E-W in the Sost and Misgar Units, whereas they are clearly NW-SE in the Gujhal Unit. Several deformation events have been recognized. A mid-Cretaceous event is testified by the folded succession cropping out below the Cretaceous Tupop and Darband Formationsin the Sost Unit. Mid-Cretaceopus granodioritic intrusives, some of which have been dated at about 100 Ma, crossing previously formed shistosity, have been observed along the contact between the Gujhal Unit and the Karakorum Axial Batholith, in the Misgar Unit and the Karakorum Axial Batholith, and in the Misgar Unit, indicating a widespread orogenic event. Important post-Cretaceous thrusting is testified by the deformation of the Cretaceoussediments and also by stacking of Eocene intrusives in the Yashkuk area. North vergent tectonic transport seems to be followed in time by south vergent active, and are due to the prosecution of indentation phenomena between India and Eurasia.
Key words: Structure, Hunza valley, Karakorum.

Z/38. Zanchi, A., 1993a. Structural evolution of the North Karakoram cover, north Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society of London, Special Publications 74, 21-38.

The oldest deformational structures recognized in the Karakoram sedimentary cover north of the Karakoram Axial Batholith (KAB) consist of an E-W deformed belt composed of Permian-early Cretaceous sediments. This belt is overlain with a stratigraphical unconformity by the Cretaceous Tupop conglomerates and subsequent Late Cretaceous marine sediments. In the Chapursan Valley a complex and polyphase antiformal stack consisting of a Permian to Cretaceous succession was recognized. Post-Cretaceous northward and northeastward directions of transport are shown by slip vectors along thrust planes and by fold axes in the Chapursan Valley, whereas NW-SE-trending folds due to northeastward transport were observed in the Shimshal Valley. The north-vergent structure is crossed by successive north-dipping thrusts along the northern side of the Chapursan Valley and along the contact between the sedimentary cover and the northern continuation of the KAB.
The last tectonic phase recognized in the Chapursan Valley caused the activation of an important set of E-W-orientated sinistral strike-slip faults. In the Shimshal Valley, large E-W sinistral and NW-SE dextral faults are present as well, and may be interpreted as a consequence of a NW-SE-directed simple-shear due to deformation along major NW-SE dextral strike-slip faults.
The sedimentary cover of the Karakoram was deformed under anchimetamorphic conditions in the Chapursan Valley, whereas sericite to muscovite low-grade metapelites with occurrence of chloritoid, epidote and biotite are present in the lower Shimshal Valley. Near the Shimshal Pass, andalusite, garnet, muscovite and biotite were found in phyllites at the contact aureole of an important belt of large previously unknown granitic bodies.
Key words: Sedimentary cover, structure, Hunza, Gilgit, Karakoram.

Z/39. Zanchi, A., 1993b. Structural history of the sedimentary cover of the North Karakoram terrane in the upper Hunza valley (Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 82.

The Karakoram terrane belongs to the peri-Gondwanian blocks rifted from Gondwana during Permian and accreted along the southern Eurasian margin before collision with the Indian plate. The Karakoram block is located between two mayor suture zones: the Shyok Suture Zone to the South and the Rushan-Pshart suture to the North.
The Karakoram microplate includes a thick sedimentary cover, which is mainly Paleozoic in the western termination and Permian to Cretaceous in the central and eastern area. In the Hunza valley the cover consists of a thick pile of poorly metamorphic Permian-CretaCeOUS sediments cropping out north of the Karakoram Axial Batholith (KAB).
The sedimentary cover of the North Karakoram terrain is composed of three main structural units: the Guhjal, Sost and Misgar Units characterized by different stratigraphic and tectonic evolution. Folds and thrust surfaces generally trend E-W in the Sost and Misgar Units, whereas they are clearly NW-SE in the Guhjal Unit.
Several deformational events have been recognized on the basis of structural and geological analyses. A “mid-Cretaceous event” is testified by the folded succession cropping out below the Cretaceous Tupop and Darband Formations in the Sost Unit. Mid-Cretaceous granodioritic intrusives, some of which have been dated at about 100 Ma, crossing previously formed schistosity, have been observed in the region. Important post-Cretaceous thrusting is testified by the deformation of the Cretaceous sediments and also by stacking of Eocene intrusives in the Yashkuk area. North vergent tectonic transport seems to be followed in time by south vergent thrust motion. Complex strike-slip faults are successively active, and are due to the prosecution of indentation phenomena between India and Eurasia. Metamorphic conditions range between very low and low grade, which is reached in the deepest part of the Ghujal Unit. Andalusite is generally widespread around the intrusives, indicating low-

pressure conditions, Field work was carried out in during two field seasons (1991-1992), leading to the preparation of a preliminary geological map which is presented in the poster section. Three main geological transects from the KAB to the Misgar Unit have been reconstructed: 1) from Shimshal village to the Khunjerab pass through the Doesam and Chapchingal Pir, 2) along the Hunza and nearby valleys (Shikarjerab, Abgarch and Khudabad valleys) and along the Yaskuk glacier and the western part of the Chapursan Valley.
Key words: Sedimentary cover, structure, Hunza, Gilgit, Karakoram.

Z/40. Zanchi, A., 1994. Structure evolution of Hunza Karakorum. Proceedings of the International Symposium on the Karakorum and Kunlun Mountains, 31-43. Meteorological Institute, Beijing.

Key words: Structure, Hunza, Karakoram.

Z/41. Zanchi, A., Angiolini, L., De Amicis, M., Gaetani, M. & Le Fort, P., 1999. The new digital geological map of Central-Western Karakorum. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 187.

The new map of central-western Karakorum, presented in a preliminary version at the XII Himalayan Workshop held in Rome in 1997, has been completed and is now available in a digital format (Arclnfo covers). The mapped area (fig. 1) includes the sedimentary cover of the North Karakoram Terrain and the northern portion of the Karakorum central granitoid belt. The latter has been almost entirely mapped by P. Le Fort and represents the original base of the geological map recently published at 1:250,000 scale by Le Fort & Gaetani (1998). The new map summarizes the fieldwork carried out in Central Karakoram during the last years. Due to the lack of reliable topographic maps at the time of the fieldwork, mapping was directly performed using copies of three high resolution Spot images (pancromatic image with a pixel size of 10m) which have been printed at a 1:50,000 scale. The eastern part of the study area, from Lashkargaz to Babagundi Ziarat (Chapursan Valley) has been redrawn using the digital Spot image as a base after georeference and correction by a Geographic Information System (ILWIS 2.1).As far as concern the area located west of Lashkargaz, Spot images were available only in a photographic format and thus an automatic correction of the deformed images was not possible. The geological map has thus been redrawn on the 1:100,000 Russian map of the world, enlarged at a 1:50,000 scale, which represents a very precise and updated (1987) topographic base with contour intervals at 40 m. Due to the good quality of the topographic informations provided by this map together with the analysis of the pancromatic images, we have extended the map out of the boundaries of the area directly surveyed, over large part of the Afghan watershed region.
The database related to the map includes three topological levels of information:
-polygons, including about 8,000 geological units:
-lines, representing linear elements as faults, thrust lithological boundaries, etc. subdivided in about 30 layers. Topographical informations dircetly derived from the available cartography are also included within this database points, which represent the location of mesoscopic structural observations, sample locations, position of stratigraphic sections, etc. The new version of Fieldlog 3.1 (Geological Survey of Canada, 1998), a relational database which works in strict connection with Autocad 13-14 has been used for this purpose. Through Fieldlog, all kinds of structural data and informations related to the collected samples may be easily managed and represented in the digital map.
The final scale of publication will be 1:150,000, in order to fit the previous map of the Central Eastern Karalorum (Zanchi & Gaetani, 1994). The map represents an important step in the understanding of the geological structure of the region.
Key words: Digital map, Karakoram.

Z/42. Zanchi, A. & Gaetani, M., 1994. Introduction to the geological map of the north Karakorum terrain from the Chapursan valley to the Shimshal pass 1:150,000 scale. Rivista Italiana de Paleontologia i Stratigrafia 100, 125-136.

Key words: Geological map, North Karakoram, Gilgit.

Z/43. Zanchi, A., Gaetani, M., Angiolini, L., De Amicis, M. & Poli, S., 1997. The 1:150,000 new digital geological map of the North Karakoram terrane from the Chapursan valley to Morich Gol (Northern Pakistan). Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 239-240.

Between August and September 1996 we crossed the sedimentary cover of the North Karakorum Terrain, from the Hunza valley to Chitral passing through the Chillinji, Karambar and Shah Jinali passes. One of the main purpose of the expedition was to produce a geological map of the whole area, according to the stratigraphic and structural framework established during previous work and to the new observations performed in 1996.
Due to the lack of reliable topographic maps, field mapping was directly realized on pancromatic Spot images printed at a 1:50,000 scale. Correction and georeferencing of the images was obtained with current GIS software (ILWIS 1.4 ITC-Netherlands). Lithological boundaries, major tectonic structures and other topographic informations were digitized in a vector format on separate layers above the georeferenced images leading to a high level of precision. Data concerning mesoscopic structural observations and sampling were included using Fieldlog, a special multirelational database developed by the Geological Survey of Canada for mapping purposes. Finally, polygonization and map production was performed with standard ARC-INFO software.
Three preliminary sketchs of our new map are presented in the poster. The first map includes the area between the upper Chapursan valley and the Chillinji (Karambar) region. From north to south we crossed the western prosecution of the Sost Unit (Zanchi & Gaetani, 1994) which is bounded to the south by the Upper Hunza Fault. South of this post-Cretaceous north-vergent thrust the Permian to Mesozoic Guhjal Unit of the Hunza Valley is tectonically associated with the Tas Kupruk Unit, and with a complete Ordovician to Permian section of the Paleozoic, (Gaetani et al., 1996). Complex superposed folding in part post-dating thrust stacking were recognized around Chillinji.
The second area is located north of the Karambar pass, where a poorly deformed Late Carboniferous succession was recognized on the basis of brachiopods assemblages (Angiolini et al., this vol.).
The third sector includes the area from the Shah Jinali pass to the Morich Gol in the Chitral region. From the Shah Jinali pass to the west we crossed from SW to NE the western prosecution of the Tas Kupruk Unit, the Paleozoic Lun Slates (Devonian), a narrow belt of metabasites (plagioclase-hornblende amphibolites) including small amounts of serpentinites with olivine and pyroxene relics, marbles with biotite-sillimanite metapelites, and finally the Late Paleozoic-Mesozoic carbonatic Atark Unit. Complex superposed folding and sinistral strike-slip shearing are characteristic of the structural framework of this area. The amphibolite-serpentinite belt represents the easternmost prosecution of similar complexes described by Buchroithner and Gamerith (1986) in the Arkari and Tirich Gols and may represent the remnant of a suture zone now coincident with the Tirich Mir Fault Zone, separating the Karakoram Block from the East Hindu Kush block. According to available data, the intrusion of the mid-Cretaceous Tirich Mir pluton post-dates the emplacement of the ampbibolitic belt. Pre-Late Cretaceous suturing between Karakoram and Hindu Kush is also enhanced by the occurrence of Reshun-like conglomerates in the Atark unit, which suggest a common history for the two blocks since that period.
It is worth noting that, although mapped more than 10 years ago by the Austrian teams, and despite its structural importance, the presence of these basic and ultrabasic rocks was completely ignored in the new 1996 map of North Pakistan compiled by Searle and Khan (1996).
Key words: Digital map, Tectonics, Chapursan, Karakoram.

Z/44. Zanchi, A., Gaetani, M., Angiolini, L., De Amicis, M. & Sironi, M., 2001. The 1:100.000 Geological map of Western-Central North Karakoram terrain (Northern areas, Pakistan). Journal of Asian Earth Sciences 19, p.79.

Key words: Mapping, Karakoram.

Z/45. Zanchi, A., Gaetani, M. & Poli, S., 1997. The Rich Gol metamorphic complex: evidence of separation between Hindu Kush and Karakoram (Pakistan). Comptes Rendus del' Academie des Sciences Paris, Sciences de la terre et des planètes 325, 877-882.

The westernmost part of the Karakorum belt and its prosecution along East Hindu Kush includes: 1) the southern portion of the Tash Kupruk Unit; 2) the Shah Jinali Phyllites; 3) the Rich Gol Metamorphic Complex (RGMC), a narrow belt of high-grade metabasites with serpentinites and metapelites, which forms a narrow strip along the Tirich Mir Fault, separating the Atark Unit (Hindu Kush?) from Karakorum metasediments. The RGMC may represent the easternmost part of similar complexes described around the Tirich Mir and may be linked to the boundary between Karakorum and East Hindu Kush.
Key words: Metamorphism, Hindu Kush, Karakoram.

Z/46. Zanchi, A. & Gritti, D., 1995. Multistage Structural Evolution of Northern Karakoram (Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The structural setting of the sedimentary cover of the Karakorum (fig. 1) is well exposed in the uppermost Hunza Valley, where several expeditions were carried out (Gaetani et al., 1990; Zanchi, 1993; Gaetani, 1994. General mapping and structural analysis were extensively performed in the Kundil, Borom, Shikarjerab and Abgarch side valleys located around Sost, where some of the most intriguing structures of the belt are exposed (fig.2). The mid-Cretaceous unconformity described by Gaetani et al. (1990) is exposed above Khudabad in the Borom and Kundil valleys in the southern part of the Sost Unit. Here the mid-Cretaceous deformed belt is covered by the Tupop Conglomerate and by the Late Cretaceous.
Below the unconformity folded limestones show E-W trending folds with subvertical axial planes; transposition and the slaty cleavage developed in the folded Jurassic marls and slates belonging to the deformed belt.
Along the top of the Borom and Kundil valleys thrust sheets of the Sost Unit override the Late Cretaceous sediments as well as the thrust sheet of the Guhjal Unit. E-W trending drag folds showing northward tectonic transport are present belt in the Darband Formation along thrust planes of the Sost Units. NW-SE folds and thrust planes developed in the the Guhjal Unit (fig.3), which also override the Cretaceous sediments along the Upper Hunza Fault, the major tectonic boundary between the Sost and Gubjal Units.
South-vergent thrust stacking was active along the northern part of Sost Unit and lead to the formation of a complex em. antiformal stack with strong lateral geometrical variations. Whereas in the Yashkuk Glacier area the western prosecution of the Sost Unit mostly records north-verging thrust stacking (Zanchi, 1993), around Sost south-vergent thrust sheets are dominant. In the Borom valley a large part of the Permian to Triassic successions show large be overturned concentric folds, indicating south vergent motion. Further east the same succession is tectonically reduced with intensive thickening of the Gircha Formation due to development of tight folds with subvertical axial planes and ring reverse faults.
The northern flank of the antiformal stack, which is overthrusted by the Misgar Slates moving along the south-vergent Northern Fault, is crossed by the Misgar Fault Zone north of Sost, fonning a complex system of WNW-ESE trending tectonic flakes due to very intensive folding and at least partly successive strike-slip motion. The fault zone wasidentified by Gaetani Ct al., (1990) and located in the sedimentary thrust sheets of the Sost Unit; these authors indicated dextral motion on the basis of the displacement shown by-the tectonic boundary between the Misgar and Sost Unit along the Northern Fault. Ogasawara (1992) also indicated dextral movements along a mylonitic shear zone developed around 60 Ma in the Misgar area near the Misgar Fault of Gaetani et al. (1990) and also including mylonitic metagranitoids intruded in the Misgar Unit. A few data collected along the Misgar Fault of Gaetani indicate complex and polyphasic fault motions along the structure. Complex reverse faulting, dextral and sinistral strike-slip movements were observed along the Karakorum Highway and in the Shikarjerab valley. Oblique dextral-reversal components indicated by calc-mylonites along thrust surfaces slightly south of the Misgar Fault Zone also indicate that transpression might be partly coeval with the embrication of the northern side of the stack.
The Misgar Fault Zone seems to be the westward prosecution of important dextral en echelon strike-slip faults observed in the upper part of the Skimshal. The steeply dipping E-W thrust surfaces of the central and southern part of the Sost stack are generally remobilized by sinistral strike-slip faults. During this phase microfolds with subvertical axes and conjugated kink bands developed in the slates of the unit, deforming previous foliations.
Dextral movements along major WNW-ESE to NW-SE fault zones (Misgar Fault) and possibly coeval pervasive siistral movements along inherited E-W faults may be due to post-collisional dextral shearing active along the right corner of the Indian Indenter in extreme conditions of deformation. Coeval movements along mechanically unfavourable fault planes may be explained by strain accommodation in discrete domains bounded by E-W faults occurring along a mayor dextral fault zone. Activation of sinistral motions along E-W faults is probably due to the importance of inherited structures, represented by high-angle reverse faults formed during previous compressional phases.
Key words: Structure, metamorphism, Hunza, Karakoram.

Z/47. Zanchi, A. & Gritti, D., 1996. Multistage structural evolution of Northern Karakoram (Hunza region, Pakistan). Tectonophysics, 260, 145-165.

Detailed mapping and structural work in Upper Hunza Valley, Pakistan, have enlightened the tectonics and the structural evolution of the sedimentary cover of Northern Karakorum. This includes the Northern Sedimentary Belt (NSB) with the Guhjal and Sost Units (Permian-Cretaceous), cropping out north of the Karakorum Axial Batholith (KAB); the NSB is bounded to the north by the Misgar Unit, consisting of slates of unknown age. In the Sost Unit a mid-Cretaceous deformed belt is sealed with a strong angular unconformity by the Late

Cretaceous formations. Folds within the mid-Cretaceous belt possibly indicate north-vergent transport. Stacking of NE- to N-vergent thrusts sheets postdates the deposition of Cretaceous sediments, which are largely included within tectonic slices developed along the southern flank of the Sost stack. The southern part of the stack is in turn intruded by the Palaeogene Kuk pluton belonging to the Batura Unit of the KAB.
S- to SSE-vergent thrusting was successively active, stacking steep north-dipping thrust sheets along the northern side of the Sost Unit, forming a complex antiformal stack, well exposed around Sost. High angle pure dip-slip reverse and oblique dextral motions are recorded by fault-slip data and calc-mylonites along major faults, forming a transpressive fault zone close to the contact between the Sost and Misgar Units. During this stage, the Misgar Unit was thrusted southward above the Sost Unit along the Northern Fault. Prosecution of dextral motion was also active afterwards along the boundary between the two units. The importance of wrench tectonics is also indicated by widespread activation of E-W sinistral strike-slip faults in the whole study area, generally moving along pre-existent fault planes.
Key words: Structure, Hunza, Karakoram.

Z/48. Zanchi, A., Poli, S., Fumagalli, P. & Gaetani, M., 1999. Mantle peridotites along the Tirich Mir Fault (NW-Pakistan): Pre-mid Cretaceous accretion of the Karakorum terrane?. Terra Nostra 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 186.

Mesozoic progressive accretion of Perigondwanan terranes along the southern margin of Eurasia, before the collision of the Indian plate, has been so far recognized b~’ several authors, even if the structural relationships, number, identity and evolution of these blocks are still poorly known. In Pakistan, the Main Mantle Thrust marks the boundary between India and the Mesozoic Kohistan arc, whilst the Northern Suture separates Kohistan from the Karakoram, which was located along the southern margin of the Mega Lhasa.
Ultramafic bodies, along with melanges or syntectonic sediments, have been so far largely used as a marker of sutures or major fault zones between the different terranes, although well documented mantle peridotites are rare. Our recent discovery of a narrow, but more than 150 km long, belt of deformed mafic and ultramafic sandwiched between East Hindu Kush and Karakoram (Zanchi et al., 1997) along the Tirich Mir Fault, Chitral, NW-Pakistan provides a strong argument for the location of the northwestern boundary of Karakoram, as previously suggested merely on the basis of paleogeographic reconstructions (Gaetani, 1997).
In 1996 and 1997 during two field expeditions, we have found a narrow belt of amphibolites, metagabbros, peridotites, gneisses, and quartzites, here named the Tirich Boundary Zone, (TBZ) extending from the Shah Jinali Pass to the Barum valley. North of the Shah Jinali Pass, the TBZ disappears along the Tirich Mir Fault, which prosecutes northward along the Yarkhun
Valley into Afghanistan, merging into a complex system of south-vergent thrusts which form the northern boundary of the Karakoram. West of the Tirich Mir, the same rocks still occur in the Sunitz, Arkari and Lutko valleys. From the Lutko valley the belt extends westward into the poorly known mountains of Nuristan, Afghanistan. Well-preserved spinel lherzolites and harzburgites (loss on ignition 1-3 wt0/o) have been found in the Tirich Gol, in the Barum valley, and in the Arkari Gol, whereas schistose serpentinites predominate in the Rich Gol. Whole-rock analyses show high MgO contents, coupled to low CaO, A12O3, Na2O and TiO concentrations that indicate the depleted signature of TBZ peridotites. The depleted character is further confirmed by the mineral chemistry of olivine, clinopyroxene, orthopyroxene and spinel. Microstructural and petrological features unequivocally indicate a mantle origin for these ultramafic bodies, equilibrated at temperatures ranging from 10000C to 11000C on the basis of currently available geothermometers. Peridotites are tectonically coupled to partially metamorphosed igneous bodieds, which includes a whole range of rocks from hornblende gabbros, to cumulitic hornblendites to quartz-diorites. Metamorphic rocks lying south of the ultramafic-mafic complex mainly consist of quartzites, amphibolites and garnet-sillimanite (kyanite)-biotite gneisses and mica schists, locally displaying k-feldspar and migmatitic textures. Widespread greenschist facies reequilibration affect most units.
The high temperature attained by metasediments, by the mafic suite and by the peridotitic bodies, and the common reequilibration path through amphibolite to greenschist facies conditions suggest an early arrangement of the TBZ sequence, even though all current contacts are always of tectonic origin. Absence of an ophiolitic sequence s.s., relatively low temperatures of equilibration for lherzolites and harzburgites, along with coupling with a deep crustal sequence might suggest a sub-continental character of the TBZ peridotites. Therefore, this belt might represent a fragmented crust-mantle boundary developed either on a passive continental margin or along a zone of attenuated continental crust.
The mid-Cretaceous Tirich Mir Pluton intrudes this belt, clearly post-dating magmatism, metamorphism and deformation of the unit, which may be related to an early collision of the Karakoram terrane with the southern section of the Pamir belts (Pashkov and Budanov, 1990; Gaetani et al., 1993).

Key words: Tectonics, structural geology, peridotite, Tirich Mir fault, Chitral, Hindukush.

Z/49. Zanchi, A., Poli, S., Fumagalli, P. & Gaetani, M., 2000. Mantle exhumation along the Tirich Mir Fault Zone, NW Pakistan: pre-mid-Cretaceous accretion of the Karakoram terrane to the Asian margin. In: Khan, M.A[sif], Treloar, P.J., Searle, M.P. & Jan, M.Q. (eds.), Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya. Geological Society, London, Special Publication 170, 237-252.

The left-lateral strike-slip Tirich Mir Fault, Chitral, NW Pakistan, is associated with a belt of peridotites, metagabbros and gneisses named the Tirich Boundary Zone (TBZ), separating the Late Paleozoic-Mesozoic units of the East Hindu Kush from the Paleozoic successions of the Karakoram block. These rocks were metamorphosed up to upper amphibolite facies conditions, followed by a greenschist facies overprinting, and then thrust on to very low-grade metasediments; they were finally intruded at shallow levels by the mid-Cretaceous Tirich Mir pluton. Ultramafic rocks along the fault zone include well-preserved spinel lherzolites and harzburgites (Tirich Gol, Barum valley, Arkari Gol), whereas schistose serpentinites occur in the Rich Gol. Whole-rock analyses and mineral chemistry of olivine, clinopyroxene, orthopyroxene and spinel from these peridotites show a depleted signature. Microstructural and petrological features suggest a mantle origin or these ultramafic bodies, which equilibrated at temperatures ranging from 100-1100ºC, peridotites are faulted against partially metamorphosed igneous bodies including hornblende-gabbros, hornlblende-gabbros, hornblende cumulates and quartz-diorites. Metamorphic rocks of the TPZ, which lay south of the ultramafic-mafic complex, include quartzites, amphibolites, garnet-sillimanite (± kyanite ± K-feldspar)-biotite gneisses and mica schists, locally displaying migmatitic textures.
A sub-continental character of the peridotites indicated by low temperatures of equilibration and by the presence of a deep crustal sequence. These characters along with the absence of an ophiolitic sequence may suggest that the TBZ represent a fragmented crust-mantle boundary developed along a zone of attenuated continental crust. The TBZ is interpreted as a sheared lithospheric section of a Jurassic-Early Cretaceous orogenic complex, formed as a consequence of the accretion of the Karakoram terrane to the southern side of the Pamir belts, which were progressively accreted to the Asian margin.
Key words: Tectonics, structural geology, petrology, Tirich Mir fault, Chitral, Hindukush.

Z/50. Zanettin, B., 1955. Italian Karakorum Expeditions 1953–55, notes on the petrography of the area extending from the Haramosh Group to the Kosar Gunge Group (northern side of the Indus Baltistan). La Ricerca Scientifica, anno 26, No. 11.

Key words: Petrography, Haramosh, Baltistan.

Z/51. Zanettin, B., 1956. Notizie petrografiche sull territorio compreso fra i gruppi dell'Haramosh e del Koser Gunge (versante settentrionale dell'Indo Balti). La Ricerca Scientifica 26, 3394-3404.

Key words: Petrography, Haramosh, Baltistan.

Z/52. Zanettin, B., 1957. Motivi petrografici essenziali osservati nella regionae centrale dell Caracorum. Rendiconti della Societa Mineralogie Italiana 13, 397-411.

Key words: Petrography, Central Katakoram.

Z/53. Zanettin, B., 1961. Motivi petrologici petrogeneci nel Karakorum Centro–Merdiionale. Institute of Geology & Mineralogy, Padova University, Memoir 3, 1–41

Key words: Petrology, Petrogenesis, Central Karakoram

Z/54. Zanettin, B., 1964a. Tertiary granitic masses of diverse origins in the south-central Karakorum. 22nd International Geological Congress 11, 514-530.

Key words: Petrography, petrology, Tertiary granites, south-Central Karakoram.

Z/55. Zanettin, B., 1964b. Geology and petrology of the Haramosh Mangu Gosor area. Italian Expedition to the Karakorum (K2) and Hindu Kush, (Leader A. Desio). Scien. Report III, vol. I, Brill. Leiden, 253p.

Key words: Geology, petrography, granitoids, Haramosh, Mango Gosor, Karakoram.

Z/56. Zanettin, B., 1964c. Molteplicita de processi nella genesi de masse grantiche terziarie nel Caracorum Centro-Meridionale. Consiglio Nazionale de Ricerche, Centro de Studi per la petrograpfia e la geologia, 3-20.

Key words: Tertiary granitoids, Modes of genesis, Central Karakoram.

Z/57. Zanettin, B. & Callegari, E., 1960. Chimismo di rocce vulvaniche e plutoniche del Karakorum Centro–Meridionale. Instt. Geol. Min., Padova University, Memoirs, 21, 3 - 38.

Zenettin made substantial contribution to the petrography and petrology of igneous rocks of the western and central Karakoram range. In this paper the authors gave details of the geochemistry of volcanic and plutonic rocks of the central Karakoram.
Key words: Geochemistry, volcanic, plutonic rocks, Central Karakoram.

Z/58. Zaninetti, L. & Bronnimann, P., 1975. Triassic Foraminifera from Pakistan. Rivista Italiana di Paleontologia e Stratigrafia, 81(3), 257-280.

The Landu Nala bed, Surghar Range, Pakistan, has 2 Triassic microfossiliferous intervals. The 1st, containing Endothyranelles and Meandrospira pusilla, is attributed to the Lower Anisian. This calcarenitic unit is situated between the subadjacent Khatkiara sandstones and the dolomitic Kingriali formation. The latter formation, constituting the 2nd interval, contains Involutina comparable to those of Espahk formation (Iran). The probable age of the microfauna is Ladinian. At the base of the Samana Suk bed, Samana Range, Pakistan, an important association of Triassic Foraminifera, especially Involutinidae, was identified. Compared to the microfauna of the Espahk limestone, this association seems younger than that of the Kingriali formation in the Landu Nalu bed. The age for the Samana Suk bed is estimated at Middle to Upper Triassic (Ladinian to Carnian).
Key words: Palaeontology, Foraminifera, Triassic.

Z/59. Zanin Buri, C., 1965. A new Permian epimastopora (calcareous alga) from Hunza valley (Western Karakorum). In: Desio, A. (ed.), Italian Expeditions to the Karakorum and Hindu Kush. Scientific Report 4(1), 79-88. Brill, Leiden.

While examining samples coming from a section made in the Permian of Hunza vally (right side of Chapursan river: on the way to Khudabad-raminj) during Prof. A. Desio's expedition, I recognized the presence of an algel form belonging to Epimastopora, unknown until now in this region. The specimens we examined have been taken from the samples of Girch formation with a thickness of 6000 m, whose upper part os formed by brown and black arenaceous layers with small interpositions of dolomitic limestone, while lower part is formed by light – coloured quatz – sandstones. Our specimens are coming from the calcareous layers in between the inferior and superior member of the formation.
Epimastopora forms are rather frequent and their presence has been noted by several authors in Upper Paleozoic of Asia, America and Europe. It has to be remembered by the way, that the nearest geographic finding is given by the species Epimastopora alpine Herak, coming from the Darvasian of Davas (central Tajikistan – NW Pamir). This spcies, in opposition to the one I have examined, has been found in association with some other species of calcareous Algae.
Notwithstanding the fact that it has frequently been noted, genus Epimastopora is still not very well known as we are not in a possession of sure data to recognize it exactly.
From stratigraphical point of view it has a great importance, having a limited vertical distribution: its oldest forms aooear in Upper Carboniferous and most recent ones are not going over Permian; each species occurs even shortest intervals. For what concerns ecology, Epimastopora testifies warm marine environment such as littoral sea.

Key words: Palaeontology, Permian alga, Hunza.

Z/60. Zarin, A., Ahmad, N. & Faridullah, 1978. Geology of the area between Saidu Sharif and Pir Baba. M.Sc. Thesis, University of Peshawar, 96p.

This area is occupied by metamorphosed sedimentary rocks (politic to calcareous schists) and granitic gneisses (The Ilum granite), with sheets of amphibolites.
Key words: Metasediments, granitoids, Swat, Buner.

Z/61. Zeb, A., 1983. Geochemistry of Tora Tiga complex, southern Dir District. M.Sc. Thesis, University of Peshawar, 108p.

The Tora Tigga complex sits in the hanging wall of the Indus suture in south-western Dir. It is a part of the Kohistan terrain. This ultramafic body comprises hornblendites, a range of pyroxenites, and peridotites, as given here under Banaras and Ghani (1982), and Jan et al. (1983). Zeb provided preliminary geochemistry of the rocks, which can be seen in Jan and Tahirkheli (1990).
Key words: Ultramafic, mafics, plagiogranite, geochemistry, Dir

Z/62. Zeb, M.A., Ajmal, M. & Asif, M., 1988. Petrology and economic significance of barite deposits of Hazara. M.Sc. Thesis, University of Peshawar, 52p.

Key words: Economic geology, barite, petrology, Hazara.

Z/63. Zeilinger, G., Arbaret, L., Burg, J.P., Chaudhry, M.N., Dawood, H. & Hussain, S.S, 1998. Structures in the lower units of Kohistan arc, Northwest Pakistan: Preliminary results. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 224-227.

For further details, consult the following account.
Key words: Structure, lineation, Kohistan.

Z/64. Zeilinger, G., Burg, J.P., Chaudhry, M.N., Dawood, H. & Hussain, S.S., 2000. Fault systems and palaeo-stress in the Indus Suture zone (NW Pakistan). Journal of Asian Earth Sciences 18, 547-559.

Analysis of fault-striations measured in the Kohistan part of the Indus Suture Zone (NW Himalayas, Pakistan) has been carried out to document dynamic evolution during the brittle stage of the collision of India and Asia. Processing of the data with a direct inversion method identified four stress fields, which were chronologically ordered from field evidence as SSE-NNW compression, E-W compression, radial extension and SSW-NNE compression. The last corresponds to the present-day stress field defined from seismic activity. The earlier stress fields are related to times during the Miocene, when convergence-related stresses were disturbed by the formation of the nearby Nanga Parbat and Indus syntaxis.
Key words: Structure, tectonics, stress fields, Indus Suture Zone.

Z/65. Zeilinger, G., Burg, J.P., Schaltegger, U. & Seward, D., 2001. New U/Pb and fission track ages and their implication for the tectonic history of the Lower Kohistan arc complex, Northern Pakistan. Journal of Asian Earth Sciences 19, 16th HKTI workshop special abstract issue, p.79.

The Kohistan arc complex separates the Indian and Asian plates in NW Pakistan. It was formed as an Island arc during Mesozoic times. Accretion to Asia and subsequent thrusting onto the northern margin of the Indian plate along the northward dipping Indus suture zone (ISZ) constitute the collisional history. The early tectonic evolution of the arc can be subdivided into 2 stages: (1) a juvenile stage (estimated at ca. 110±95 Ma): lithospheric growth through partial melting of a fertile mantle in an intraoceanic subduction environment and SW-thrusting expressed by anastomosing shear zones in the southern, i.e. lower part of the arc imposed by

subduction of the Tethys oceanic crust; and (2) an intra-arc rifting stage (around 80 Ma) with the emplacement of large bodies of gabbronorite and of felsic dykes. We will present two groups of new ages obtained in the lower Kohistan arc complex: (1) crystallization ages of gabbroic to granodioritic intrusions re¯ecting the early arc related history and (2) zircon and apatite fission track (FT) cooling ages related to the younger continent/arc±continent collision and post-collisional uplift.
Key words: Geochronology, U-Pb dating, tectonic history, Kohistan arc.

Z/66. Zeilinger, G., Schaltegger, U., Burg, J.P., Chaudhry, M.N., Dawood, H. & Hussain, S.S., 2001. Precise U-Pb ages from the Kohistan complex (Northern Pakistan) illustrate rapid formation of arc-type crust. 11th EUG Meeting, Strasbourg, J. Conference Abstract 6, p.388.

The Kohistan Arc Complex in northern Pakistan was formed in the Tethys ocean in Mesozoic times and subsequently obducted onto the Indian plate along the Indus Suture in the Late Cretaceous - Paleocene times. The tectonic evolution of the arc can be subdivided into (1) a juvenile stage (estimated at ca.110-95 Ma) involving lithospheric growth through partial melting of a fertile mantle in an intra-oceanic subduction environment; (2) intra-arc rifting (around 85 Ma) marked by the emplacement of large volumes of volcaniclastic rocks in the intra-arc extensional basin and underplating of the arc crust by gabbronorites; (3) a mature stage with Andean-type granitoid magmatism, which ceased with the India–Asia collision 60 to 40 Ma ago.
The structurally lowest levels of the Kohistan Arc Complex comprise the Jijal complex, which consists of ultramafic rocks overlain by granulite-facies gabbros. The complex is covered by a pile of metamorphic gabbroic to tonalitic dykes and sills overlain by metabasalts and metasediments. This association was intruded by partial melts of mantle origin (gabbros, tonalites, granitoids) representing the first stages of crustal growth (stage 1) in an intraoceanic arc. Precise age determinations yielded for a sub-granulitic gabbro and a granitoid sheet-like intrusion significantly discrete ages of 99 and 97 Ma, respectively; a tonalite body was emplaced into the same environment at 92 Ma. The whole complex was again penetrated by mantle melts (gabbronorites to granitoid dykes) during rifting (stage 2). A gabbronorite from the so-called Chilas Complex and a granitoid kyanite-bearing dyke yielded ages of 85 Ma and 83 Ma, respectively.
The time period for the initial arc buildup with intrusion of gabbroic to granitoid melts is constrained to a short time period between 99 and 92 Ma. Intra-arc rifting characterized by the intrusion of gabbronorites and granitoid dykes is dated between 82 and 85 Ma. The ages represent the first protolith ages from the sub-arc mantle-crust transition. Initial arc magmatism may therefore be constrained to at least three magmatic pulses of <5 m.y. duration with each magmatic cycle most likely comprising gabbroic to granitoid lithologies, pointing to rapid differentiation processes. The granitoid stocks, sheets and dykes were emplaced prior to obduction onto the Indian plate.
Key words: Geochronology, U-Pb dating, tectonics, Indus suture, Kohistan arc.

Z/67. Zeitler, P.K., 1980. The tectonic interpretation of Fission-Track ages from the Himalayan Ranges of Northern Pakistan. M.A. Thesis, Dartmouth College, 92p.

Fission track ages of sphene, zircon and apatite form rocks collected along the Swat valley and from Hunza 9north Pakistan) date the recent uplift history of this region. A major E-W fault, the Main Mantle Thrust (MMT) or Patan Fault crosses the Swat valley and separates regions of markedly different uplift history. Ages ranging from 50 to 55my for apatite were obtained from the region north of this fault. To the south the ages range are 20 to 25my for sphene, 17 to 26my for zircon and 16 to 23my for apatite. This distribution of ages indicates either that differential uplift occurred across the MMT prior to about 15 my, or that this faulty has brought together terrains of differing uplift history. Should the latter have been the case, the fission track data indicate that the faulting took place between 15 and 20my at depths of between 3.5 and 6 km. As the MMT may represent the traces of collision between India and an Island arc at 53 my, the offset along this fault at 15 my determined in this study may indicate that he process of complete.
Key words: Tectonics, fission-track ages, Himalaya.

Z/68. Zeitler, P.K., 1983. Uplift and Cooling History of the NW Himalaya, Northern Pakistan. Evidence from Fission-Track and $^{40}Ar/^{39}Ar$ Cooling Ages. Unpublished Ph.D dissertation, Dartmouth College Hanover, New Hampshire 03755, 266p.

This study reports 145 fission-track and 21 40Ar/39Ar cooling ages from the Himalaya of northern Pakistan. Studies of the Himalaya are important because they provide geologists with an opportunity to test models of orogenesis in an active tectonic setting. As the Himalaya become better known and models become more quantitative, information about thermal histories and rates of uplift and erosion will be needed. This provides the motivation for this dissertation.

The cooling ages suggest, and thermal modeling confirms, that throughout the Tertiary, the cooling history of northern Pakistan was controlled by the effects of accelerating uplift and erosion. On average, from 30 Ma to the present, uplift rates increased from less than 0.1 mm/yr to 0.4 mm/yr. This uplift and erosion, however, has been variable in space as well as time. For example, over the past 10 Ma, western and southern portions of northern Pakistan have been uplifted less than 3.5 km at rates as high as 1.0 mm/yr, and the Nanga Parbat-Haramosh Massif and Hunza regions have been uplifted on the order of 10 to 15 km at rates (over the past 0.7 Ma) nearly 5 mm/yr.

The association of the Nanga Parbat-Haramosh Massif and Hunza with very young cooling ages and with rapid uplift maintained for a period of several million years is the most striking discovery made by this study. The location of these two areas at the heart of the Pamir-Himalaya Arc suggest that their anomalous behavior is linked in some way to a locally vigorous collision of India and Eurasia, possibly due to a promontory of India crust. Several of the cooling ages reported here helps constrain the emplacement ages of intrusives located in northern Pakistan. In addition, cooling ages from the southern Swat-Hazara region can be interpreted to give the time of (final?) southward thrusting of the Kohistan Arc along the Main Mantle Thrust, at about 30 Ma.

Key words: Geochronology, Ar-Ar ages, Fission-track ages, uplift, cooling, NPHM, MMT.

Z/69. Zeitler, P.K., 1985. Cooling history of the NW Himalaya Pakistan. Tectonics 4, 127-135.

Fission-track and 40Ar/39Ar cooling ages indicate that the late-Tertiary cooling history of the Himalayan ranges of northern Pakistan is largely a function of uplift and erosion. Interpretation of cooling ages which range from under 0.5 Ma to over 80 Ma suggests that during the late Tertiary, long-term uplift rates at least doubled, from under 0.2 mm/yr to in some cases well over 0.5 mm/yr. Uplift rates show strong and systematic regional variations as well which reflect the greater uplift of eastern and northern regions. The association of very rapid uplift and erosion with the Nanga Parbat-Haramosh Massif can be explained by a locally vigorous collision of India with Eurasia near a promontory of Indian crust. The resultant rapid uplift of the Nanga Parbat-Haramosh Massif reactivated the Main Mantle Thrust melange zone with a reversed sense of motion. Discontinuities in the cooling age distribution along the Main Mantle Thrust in the southern Swat-Hazara region may be the result of the thermal effects of overthrusting.

Key words: Geochronology, Ar-Ar ages, Fission-track ages, Cooling ages, NPHM, Himalaya.

Z/70. Zeitler, P.K. 1988. Ion microprobe dating of zircon from the Malakand granite, NW Himalaya, Pakistan. A constraint on the timing of Tertiary metamorphism in the region. Abstract with Program, Geological Society of America 20, 323.

The Malakand granite and Ambela syenite yield carboniferous ages. The margins of the zircons in Malaknd granites are about 45 Ma, suggesting development metamorphism.

Key words: Geochronology, U-Pb dating, Malakand granites, Ambela syenite, Himalaya.

Z/71. Zeitler, P.K., 1994. Active tectonic processes in the NW Himalaya. EOS 75, p.184.

Key words: Tectonics, Himalaya.

Z/72. Zeitler, P.K. & Chamberlain, C.P., 1990. U-Pb dating of very young leucogranites (NW Himalayas) using an ion microprobe. Abstracts, International Conference on Geochronology, Cosmochronology, and Isotope Geochemistry, 25 September 1990, Canberra.

Very young leucogranites, some only a few million years, occur in NW Himalaya in the Nanga Parbat area. The tectonic significance of these is discussed. For additional information, consult the following account.

Key words: Petrogenesis, tectonics, leucogranites, ion microprobe, NW Himalaya.

Z/73. Zeitler, P.K. & Chamberlain, C.P., 1991. Petrogenetic and tectonic significance of young leucogranites from the northwestern Himalaya, Pakistan. Tectonics 10(4), 729-741.

In the Himalaya of northwestern Pakistan, small discordant bodies of leucogranite intrude metamorphosed basement of the Indian crust. As the first step in assessing the tectonic significance of these granites, we have used the SHRIMP ion microprobe to obtain U-Pb dates on zircon. Zircons of igneous appearance are scarce in the leucogranites, and with one exception are associated with xenocrystic components, which occur as discrete grains and as cores rimmed by young zircon. Zircons of igneous appearance are high in U [5000 to 40,000 ppm], low in Th/U [0.01 to 0.05], and frequently colored a distinct blue. Xenocrystic components give a range of Proterozoic ages consistent with ages previously reported for Indian crust. In sharp contrast, zircons of igneous appearance yield clusters of concordant Tertiary ages. Two leucogranite dikes from southern localities yield rather old emplacement ages of about 35 Ma (Swat) and about 50 Ma (Naran). Together with previously determined 40Ar/39Ar and fission track cooling ages, these ages document immediate and rapid metamorphism and denudation following Eocene collision. Three leucogranite dikes from northern localities within the Nanga Parbat-Haramosh Massif are very young, having emplacement ages of about 2.3 Ma, 5 Ma, and 7 Ma. The formation and emplacement of these leucogranites during the rapid late Tertiary denudation of the Nanga Parbat region suggests to us that decompression melting may be a viable mechanism for leucogranite genesis.
Key words: Petrogenesis, tectonics, leucogranites, Himalaya.

Z/74. Zeitler, P.K. & Chamberlain, C.P., 1991. Quaternary anatexis at Nanga Parbat, Pakistan. Geological Society of America, Abstracts with Programs 23, A-135.

Key words: Quaternary, metamorphism, Nanga Parbat, NW Himalaya.

Z/75. Zeitler, P.K., Chamberlain, C.P. & Smith, H., 1990. Very young U-Pb ages from zircon and monazites of the Nanga Parbat Massif, Pakistan: Implications for metamorphic processes. Geological Society of America, Abstracts with Programs 22, p.97.

Key words: Metamorphism, NPHM, Himalaya.

Z/76. Zeitler, P.K., Chamberlain, C.P. & Smith, H., 1992. Quaternary anatexis and Neogene metamorphism at Nanga Parbat, Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 102.

Our recent geochronological work has shown that the Nanga Parbat massif (NW Himalaya, Pakistan) has experienced extensive metamorphic and igneous activity within the past 10 Ma. We summarize here our geochronological and petrological observations, which include U/Pb analyses on zircons and monazites from a variety of igneous and metamorphic units.
Tourmaline-bearing pegmatite dikes, which occur along the western and northern flank of the Nanga Parbat massif yield ages of between 2.2 and 8 Ma, based on monazite and zircon analyses. Monazite from samples of metamorphic basement yield ages ranging from 4 to 11 Ma. Finally, use of the SHRIMP ion microprobe in drilling mode reveals that zircons from two samples of schists are overgrown by thin, high-U rims which are less than 5 Ma In age, a result similar to that obtained from drilling analysis of zircons sampled along the Indus River section some 80 km to the north.
In the core of the Nanga Parbat massif, between Tato village and the northern face of Nanga Parbat, extensive migmatites are present in which pelitic units commonly show the assemblage alkali feldspar-cordierite-sillimanite-garnet. A variety of granites Intrude these migmatites and associated biotite gneisses and calc-silicates, including a 1-km stock of fine-grained, equigranular two-mica granite, dikes similar in composition to this granite, coarse tourmaline-bearing pegmatites, and several-meter-thick granite sheets containing clots of biotite. Ion-probe analyses of zircon from all these units yield well-defined ages of ~1 Ma. Zircons extracted from a sample of migmatite yield scattered ages which average about 3.5 Ma, two monazite fractions from the same sample yield concordant ages of 3.3 Ma, and 40Ar/39Ar ages of hornblende are between 1 and 2 Ma.
Migmatization within the core of the Nanga Parbat massif occurred at about 650C and 4.5 kbar. Together with the age of 3.3 Ma determined on migmatites, the petrological data confirm previous cooling-age estimates for the rapid Quaternary denudation of the Nanga Parbat masslf. Our new data suggest a mean denudation rate of .5 mm/yr for the past 3 my, indicating that unroofing of Nanga Parbat has been both extensive and rapid.
Key words: Quaternary anatexis, Neogene metamorphism, Nanga Parbat, NW Himalaya.

Z/77. Zeitler, P.K., Chamberlain, C.P. & Smith, H.A., 1993. Synchronous anatexis metamorphism and rapid denudation at Nanga Parbat (Pakistan Himalaya). Geology 21, 347-350.

The Nanga Parbat-Haramosh massif of the western Himalaya is a north-trending half-window of Indian crust that provides spectacular exposures of Precambrian basement gneisses that have been overprinted by Himalayan metamorphism. We report here petrologic data and U/Pb dates on zircon and monazite which document that Nanga Parbat gneisses underwent a Pliocene-Pleistocene episode of high-grade metamorphism and anatexis during an interval in which the Nanga Parbat massif was undergoing rapid denudation at mean rates of ~5 mm/yr. We speculate that by initiating decompression melting, this denudation may be at least partly responsible for the anatexis and high-grade metamorphism.
Key words: Denudation, anatexis, metamorphism, Nanga Parbat, NW Himalaya.

Z/78. Zeitler, P.K., Johnson, N.M., Naeser, C.W. & Tahirkheli, R.A.K., 1982. Fission-track evidence for the Quaternary uplift of the Nanga Parbat region, Pakistan. Nature 298, 255-257.

The north-striking Nanga Parbat–Haramosh Massif protrudes into the northwestern Himalaya along the axis of a great syntaxis1,2 (Fig. 1), where the Hindu Kush, Karakorum, and Himalayan ranges converge. As the Indus Suture Zone3 enters this region from the east it bifurcates into two branches, encircling what may be a docked island-arc terrane4. The southern branch (the Main Mantle Thrust) crops out on both flanks of the Nanga Parbat massif, forming a tight structural loop5. This massif and the adjacent terrane contain some of the highest peaks in the Himalaya; Nanga Parbat and the Indus River (located just 20km away) define the world's greatest continental relief (6,930 m). We report here the discovery of unexpectedly young sphene, zircon and apatite fission-track dates from the Nanga Parbat–Haramosh Massif. These dates (as low as 1.3 Myr for zircon and 0.4 Myr for apatite) imply that during the Pleistocene the Nanga Parbat region was uplifted and eroded at nearly 1 cm yr−1.

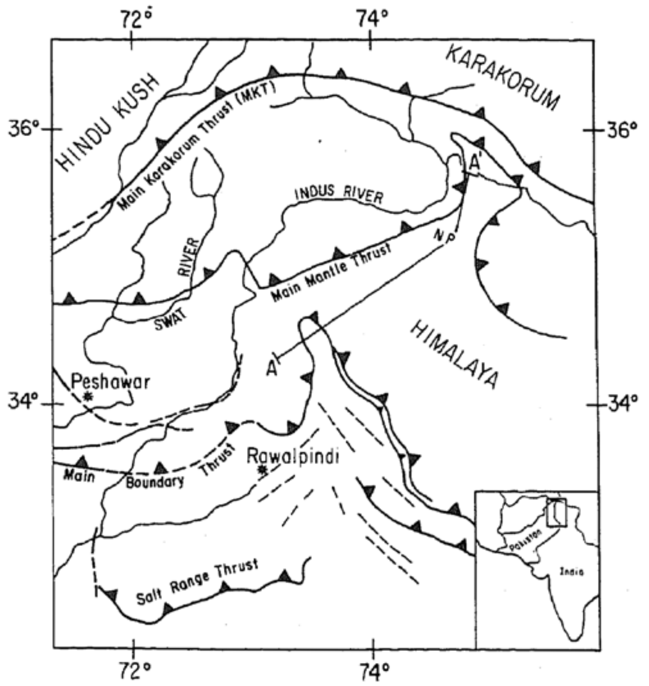

Fig. 1 Structural trends of northern Pakistan. Heavy barbed lines show suture zones and major thrust faults. Dashed lines show trends of folds in molasse sediments. NP, Nanga Parbat (8,126 m), located on Nanga Parbat–Haramosh Massif. A–A′ is line of profile

Key words: Fission-track ages, Quaternary, Nanga Parbat, NW Himalaya.

Z/79. Zeitler, P.K. & Koons, P.O., 1998. Nanga Parbat as tectonic aneurysm: a metamorphic signature of indentor-corner dynamics. Eos Transactions, Geophysical Union 79 Supplements F910.

Key words: Tectonics, metamorphism, Nanga Parbat, Himalaya.

Z/80. Zeitler, P.K., Koons, P.O., Bishop, M.P., Chamberlain, C.P., Copland, L., Craw, D., Edwards, M.A., Hamidullah, S., Jan, M.Q., Khan, M.A., Khattak, M.U.K., Kidd, W.S.F., Le Fort, P., Mackie, R.L., Meltzer, A.S., Park, S.K., Pecher, A., Phillips, W.M., Poage, M.A., Sarker, G., Schneider, D.A., Seeber, L. & Shroder, J.F., 1999. Geodynamics of the Nanga Parbat Massif, Pakistan Himalaya. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 189-190.

Within the great syntaxial bends of the India-Asia collision, the Himalaya terminate abruptly in a pair of active metamorphic massifs. Nanga Parbat in the west and Namche Barwa in the east are antiformal domes, which expose Quaternary metamorphic rocks and granites, and are loci of ferocious denudation where they are transected by major Himalayan rivers (Indus and Tsangpo). Comprehensive geophysical and geological data we have collected at Nanga Parbat support a model in which these metamorphic massifs owe their origin to erosionally induced deformation of the crust near deep gorges cut by the Indus and Tsangpo as these rivers turn sharply towards the foreland and exit their syntaxes. Primarily, the intense metamorphic and structural reworking of crustal lithosphere seen at the terminations of the Himalayan arc owes its origin to mesoscale feedbacks between erosion and tectonics.

Widely taken as the type example of a collisional mountain belt, the Himalaya have seen increasing use as a natural laboratory in which to examine a variety of collisional processes. Over the past four years, an approximately 5,000-km2 area of the central Nanga Parbat massif of the northwestern Himalaya has been the focus of our Nanga Parbat Continental Dynamics Project, a multidisciplinary study aimed at understanding how the continental lithosphere comes to be pervasively reworked during continental collision. Nanga Parbat exposes extremely young metamorphic and igneous rocks and is an ideal place to examine the specific processes involved in crustal reworking, particularly erosion, which has come to be recognized of late as a critical control on the mechanical and petrological evolution of mountain belts. The Nanga Parbat project involved the coordinated effort of numerous investigators, working in a broad range of disciplines, including the areas of geochronology, structural geology, geomorphology, seismology, remote sensing geomorphology, dynamical modeling, geochemistry, magnetotellurics and neotectonics. Together with petrologic and geomorphic studies carried out by other groups, we now have an excellent understanding of the evolution and state of the crustal lithosphere at Nanga Parbat.

The Nanga Parbat-Haramosh Massif exposes polymetamorphic Indian-plate gneisses which have been undergoing an episode of pronounced crustal reworking; this has involved pervasive deformation, young metamorphism and melting, widespread fluid flow, rapid and pronounced exhumation, and sculpting of the crust into spectacular, steep topography. Within the core of the Nanga Parbat massif, there is a bull's-eye coincidence between the massifs most extreme topography and high-temperature granulite-grade migmatites, a young and active anti formal pop-up structure, young 1-2 Ma granitoids, abundant seismicity with sharp bottom and lateral cut-offs, pronounced hydrothermal activity, steep new-surface thermal gradients, and rapid denudation documented across a wide range of timescales. These coincident features beg a simple, shared explanation.

Erosionally concentrated strain attributable to large magnitude incision by the Indus River focuses Indian Plate material from the south into the developing Nanga Parbat massif. Advection elevates isotherms beneath the massif, creating a relatively high-temperature/low-pressure region where sillimanite and dry melt are stable that coincides with a zone of anomalously low electrical conductivity. At approximately 12 km depth these relatively dry rocks interact with highly-exchanged meteoric or metamorphic water and generate vapor-present, cordierite-bearing granitic veins. The hot rock packet then passes toward the northwest, advecting isotherms, elevating the position of the brittle-ductile transition, and generating a vigorous hydrothermal system. The base of the predicted rheological transition coincides with a cutoff in observed microseismicity.

Work by J. Burg and colleagues and mapping by Chinese geologists suggests that the Namche Barwa massif in the eastern Himalayan syntaxis shares a very similar geological and tectonic setting with Nanga Parbat. We suggest that such hyperactive metamorphic massifs may be signature features of syntaxial regions, where large orogen-scale rivers such as the Indus and Tsangpo are diverted towards the foreland, rapidly cutting deep gorges as they make their steep exit from the hinterland.

Local, sub-orogen scale erosional exhumation at Nanga Parbat (and, we suspect, at Namche Barwa), fr from being overrated, is in fact of first-order importance in controlling the metamorphic, topographic, and structural

evolution of the cores of the Himalayan syntaxes. Such pervasive structural and metamorphic overprinting of old basement rocks is a fundamental geodynamic process in its own right. Ultimately, the dynamics of syntaxial metamorphic massifs may be reconciled with broader orogen-scale collision processes through the feedbacks between deformation, topographic evolution, and erosion that lead to the channeling of major river systems through the syntaxes. Our results contribute to the growing appreciation of the importance those surficial processes and crustal rheological variations have on controlling the shape, dynamics, and evolution of mountain belts, at many scales.
Key words: Geodynamic, geochronology, tectonics, NPHM, NW Himalaya.

Z/81. Zeitler, P.K., Koons, P.O., Bishop, M. L., Chamberlain, C.P., Craw, D., Edwards, M.A., Hamidullah, S., Jan, M.Q., Khan, M.A., Khattak, M.U.K., Kidd, W.S.F., Mackie, R.L., Meltzer, A.S., Park, S.K., Pecher, A., Poage, M.A., Sarker, G., Schneider, D.A., Seeber, L., and Shroder, J., 2001. Crustal Reworking at Nanga Parbat, Pakistan: Evidence for erosional focusing of crustal strain. Tectonics, 20, 712-728.

Within the syntaxial bends of the India-Asia collision the Himalaya terminate abruptly in a pair of metamorphic massifs. Nanga Parbat in the west and Namche Banva in the east are actively deforming antiformal domes which expose Quaternary metamorphic rocks and granites. The massifs are transected by major Himalayan rivers (Indus and Tsangpo) and are loci of deep and rapid exhumation. On the basis of velocity and attenuation tomography and micro-seismic, magnetotelluric, geochronological, petrological, structural, and geomorphic data we have collected at Nanga Parbat we propose a model in which this intense metamorphic and structural reworking of crustal lithosphere is a consequence of strain focusing caused by significant erosion within deep gorges cut by the Indus and Tsangpo as these rivers turn sharply toward the foreland and exit their host syntaxes. The localization of this phenomenon at the terminations of the Himalayan arc owes its origin to both regional and local feedbacks between erosion and tectonics.
Key words: Orogeny, tectonics, Nanga Parbat.

Z/82. Zeitler, P.K. & the Nanga Parbat Working Group, 1998. Crustal reworking at Nanga Parbat: The Nanga Parbat continental dynamics project. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 227-228.

A considerable amount is now known about the Nanga Parbat massif, which has been the focus of intense study over the past several years by several teams. Our ongoing Nanga Parbat Continental Dynamics Project has been using Nanga Parbat as a natural laboratory to examine processes of pervasive synorogenic crustal reworking, on the basis that the Precambrian rocks of the massif have been deeply overprinted by a recent and intense metamorphic, magmatic, and deformational episode that remains active today. We are currently synthesizing results from investigations in the areas of magnetotellurics, seismology, structural geology, tectonics and neotectonics, geochronology, geomorphology, petrology, geochemistry, and dynamical modelling in order to test hypotheses about mesoscale linking between petrologic, tectonic, and surficial processes.
The Precambrian rocks of the Nanga Parbat massif occur within a northward projection of Indian-plate basement flanked to the west and east by rocks of the Mesozoic Kohistan-Ladakh arc terrane and to the north by rocks of the Asian plate. Originally overthrust from the north (in the early Tertiary) by mafic and intermediate volcanic and plutonic rocks of the Kohistan terrane, Nanga Parbat basement has recently been exhumed by NW-directed thrusting and development of a large north-south oriented antiform. Ferocious exhumation has occurred by mass wasting and glacial erosion, with the nearby Indus River providing efficient removal of debris from the region: fluvial incision rates along the Indus are among the highest in the world, reaching 12 mm/yr (Burbank et al. 1996). The summit massif in the central portion of the antiform is ringed by concentric isograds, which culminate in cordierite-K-feldspar grade, and in this region a moderate number of undeformed granitoid dikes and pegmatites as well as a few small bodies of undeformed granite occur. To the south of Nanga Parbat, towards Babusar Pass and the relatively low-grade rocks which occur there, there is a major telescoping of isograds across what is most likely a thrust system of some sort.
Much of the exposed geology at Nanga Parbat is young or the result of ongoing rapid processes. The 7000 meters of relief defined by Nanga Parbat and the Indus River reflect unroofing rates as high as 5 mm per year, as documented at several time scales by geomorphic, petrologic, and fluid-inclusion studies. These rapid unroofing rates are also reflected in the very young cooling ages seen within the Nanga Parbat massif, with mica Ar-Ar ages of as young as 1 Ma and metamorphic monazite ages on migmatites of known P-T conditions of as young as 3 Ma; these data suggest cooling rates for exposed surface rocks of well over 200 C/m.y., and unroofing in

the past 3 Ma of some 15-20 km. Granite ages from 1 to 8 Ma indicate that emplacement in at least some places took place during exhumation, leading to the suggestion that some of the Nanga Parbat granites owe their origin to decompression melting. There is abundant evidence for fluid flow within the Nanga Parbat massif involving circulation of metamorphic and magmatic waters as well as penetration of meteoric water to depths having temperatures of some 600oC. This fluid flow and the high thermal gradients under the massif are attested to by the presence of numerous hot springs, and fluid-inclusion studies suggesting gradients over the top 3 km being some 100 C/km. Active faulting is common within the Nanga Parbat massif, and includes the substantial NW-directed Raikot/Liachar thrust, which places basement over gravels, as well as faults further outboard to the west of Nanga Parbat which have displaced rocks of the Kohistan terrane. The massif is quite active microseismically, but only to depths of some 7 km, presumably reflecting the high thermal gradients and a shallow brittle-to-ductile transition. To date we have found no evidence for significant extensional exhumation and it appears that the extreme exhumation at Nanga Parbat stems from erosion of rocks exposed by reverse faulting.
The relationship between the spatially rather limited metamorphic anomaly at Nanga Parbat and its broad geodynamic setting is an important question to which we are ultimately directing our efforts. Recent reports by J.-P. Burg and coworkers suggest that the geology and active tectonics of Namche Barwa, located at the far eastern end of the Himalayan chain, is remarkably similar to that seen at Nanga Parbat. The location of the Himalayas' two hyperactive metamorphic massifs precisely within the orogen's two great syntaxes is surely no coincidence, and raises interesting questions about the nature and evolution of indentor corners.
Key words: Geochronology, Orogeny, Tectonics, NPHM, Himalaya.

Z/83. Zeitler, P.K., Sutter, J., Williams, I.S., Zartman, R.E. & Tahirkheli, R.A.K., 1986. The Nanga Parbat-Haramosh Massif, Pakistan: Geochronology and cooling history. Geological Society of America, Abstracts with Programs 18, p.800.

Consult the following for further information
Key words: Geochronology, tectonics, NPHM, Himalaya.

Z/84. Zeitler, P., Sutter, J., Williams, I.S., Zartman, R.E. & Tahirkheli, R.A.K., 1989. Geochronology and temperature history of NPHM, Pakistan. In: Malinconico, Lillie, R.J. (eds.), Tectonics of the Western Himalayas. Geological Society of America, Special Paper 232, 1-22.

The gneisses of the Nanga Parbat Haramosh Massif (NPHM), Pakistan, experienced peak metamorphic temperature in the interval from 25 to 30 Ma, as revealed by 40Ar/39Ar cooling ages of hornblende and the ages of the youngest intrusions of the Kohistan batholith located immediately adjacent to the NPHM. 40Ar/39Ar and fission-track mineral ages indicate that the postmetamorphic cooling history of the NPHM has been controlled over the past 5 – 10 M.Y. by active tectonism associated with the Raikhot Fault, although passive uplift and erosion in response to over thrusting of the NPHM by the Kohistan Arc has been underway as well. Net cooling rate for the NPHM gneisses exposed today along the Indus River at low elevations have accelerated from 200C / m.y. at ~20Ma to 3000C /m.y. at 0 to 0.4 Ma. following emplacement of aplite dikes at about 30 to 35 Ma, portions of the Kohistan batholith adjacent to the NPHM experienced cooling rates similar to the NPHM of about 20 C/m.y. over the period of 25 to 10 Ma, but the net cooling rates fr the batholith of ~30C/m.y. over the past 10 m.y. have been much lower than those experienced within the NPHM. Ion microprobe and conventional U/Pb analyses of Zircon sjow that the protoliths for the Iskere gneiss and the structurally lower Shensgus gneiss of the NPHM are, respectively, ~1850 Ma and 400 to 500 a in age.
Key words: Geochronology, tectonics, NPHM, Himalaya.

Z/85. Zeitler, P.K., Tahirkheli, R.A.K., Naeser, C.W. & Johnson, N.M., 1982. Unroofing history of a suture zone in the Himalaya of Pakistan by means of Fission-Track annealing age. Earth and Planetary Science Letter 57, 227-240.

The uplift history of the Swat Valley and Hazara region of northwestern Pakistan has been established using 22 fission-track dates on apatite, zircon and sphene. A major fault, the Main Mantle Thrust (MMT) strikes east-west across the Swat Valley, separates regions of markedly differing fission-track age regimesm, and may be a suture zone separating an extinct island arc terrane on the north from the Indian plate to the south. Fission-track ages ranging from about 55 to 58 m.y. for sphene, 18 to 53 m.y. for zircon, and 9 to 17 m.y. for apatite were

obtained from the region north of the MMT. To the south the fission-track age ranges are 20 to 25 m.y. for sphene, 17 to 26 m.y. for zircon, and 16 to 23 m.y. for apatite. Disparate zircon and sphene ages on each side of the MMT imply different cooling histories for each side of the fault prior to 15 m.y. Similar apatite ages on both sides of the fault imply similar cooling histories during the past 15 m.y. This may indicate that faulting ceased by 15 m.y. Mean uplift rates have been derived from the fission-track data using mainly the mineral-pair method. Uplift rates in the region north of the MMT increased from 0.07 to 0.20 mm/yr during the period 55 to 15 m.y. south of the fault, uplift rates averaged in excess of 0.70 mm/yr for the period 25 to 15 m.y. During the past 15 m.y. uplift across the MMT in the Swat Valley shows no discontinuities, ranging from 0.16 mm/yr in the south to 0.39 mm/yr in the north. A plausible interpretation for the fission-track uplift data has the MMT verging to the south with overthrusting taking place at a depth between 3.5 and 6.0 km, juxtaposing two terranes that were originally separated by a substantial, but unknown distance. In this model, regional uplift followed cessation of faulting just prior to 15 m.y.
Key words: Fission track dating, Himalaya.

Z/86. Zeitler, P.K., Tahirkheli, R.A.K., Naeser, C., Johnson, N. & Lyons, J., 1980. Preliminary fission track ages from the Swat valley, Northern Pakistan. Geological Bulletin, University of Peshawar 13, 63-65.

A number of the lithologies found in the Swat Valley have been dated by the fission track method to assess and to describe the area's uplift history. Pb/U determinations made on three zircon splits obtained from the pyroxene granulite located to the north of the MMT fall nearly on Concordia at about 84 m.y. Zircon obtained from a metasediment located south of the fault give a fission track age of about 22 m.y., the same as zircons obtained from associated granites and gneisses. Thus it can be shown that the fission track ages of rocks located north of the MMT are not intrusive ages, and similarly that ages of rocks located south of the MMT must be yielding uplift ages.
Key words: Geochronology, Fission track dating, U-Pb dating, Swat.

Z/87. Zeitler, P.K., et al., 1981. Rapid uplift/erosion rates in the Nanga Parbat-Haramosh area as determined from fission-track data. Geological Society of America, Abstracts with Programs 13, p.587.

Consult Zeitler et al., 2001 for further information.
Key words: Uplift, erosion, tectonics, NPHM, Himalaya.

Z/88. Zeitler, P.K., et al., 1982. Tectonic terrains in northern Pakistan have different cooling histories. EOS 63, p.1125.

Consult Zeitler at al., 1980 for further information.
Key words: Tectonics, Northern Pakistan.

Z/89. Zeitler, P.K., et al., 1994. Crustal reworking during orogeny: An active-system Himalayan perspective. In: Program, ILIAD Workshop, Taos, New Mexico, 5-9 November, 1994.

Key words: Orogeny, cooling histories, tectonics, Himalaya.

Z/90. Zhang, Jinhua, & Bai Zhongyan, 1980. The surface ablation and its variation on the Batura Glacier. In: Shi, Y. (ed.), Professional Papers on the Batura Glacier, in Karakoram Mountains. Science Press, Beijing, 83-98.

Key words: Glaciers, ablation, Batura.

Z/91. Zhang, Xiangsong, 1984. Recent variations of some glaciers in the Karakoram Mountains. In: Miller, K.J. (ed.), The International Karakoram Project, 1, 39-50. Cambridge University Press.

In 1974-1975 and in 1978, the author was a member of the Batura Glacier Investigation Group of the Karakoram Highway Engineering Headquarters of the People's Republic of China. Studies of contemporary glaciation along the Karakoram Highway have been actively carried out and some valuable data on glacial variation gathered. During our investigations we were warmly supported by our Pakistan friends. This article is based on the geomorphological investigation together with documentary records with especial comparison to the landsat images in the 1970's and topographic maps in various years, and aims at explaining recent variations.
Key words: Landsat imaging, geomorphology, glaciers, Batura, Karakoram.

Z/92. Zhong, Xiangsong, et al., 1980. General features of the Batura Glacier. In: Shi Y. (ed.), Professional Papers on the Batura Glacier, in Karakoram Mountains. Science Press, Beijing, 8-27.

Key words: Glaciers, Batura, Karakoram.

Z/93. Zhang, Y, Xie Yingiran, Xu, Ronghua, Widal, P., & Arnaud, P. 1996. Geochemistry of granitoid rocks. In: Pan, Y. (ed.), Geologic evolution of the Karakorum and Kunlun mountains. 94-136.

Granitic rocks occurring in Kunlun and northern Karakorum belts, and Taxkorgan alkaline complex are described. The Khunjerab granitic belt in northern Karakorum extends along the border of Pakistan and China. It is composed of tonalite, monzolitic granite, K-feldspar granite and two-mica alkali feldspar granite, with isotopic ages around 100 ma. they contain 59-75 % SiO_2 and classify as calc-alkaline. Trace elements and REE data are given for the rocks; they contain high REE and LREE/ HREE = 10.3. The analyses plot in the field of volcanic arc /post collision granites and in active plate margin fields.
Key words: Granite, Kunlun, Khunjerab, Northern Karakorum.

Z/94. Zhongguo Ke Xue Yuan., 1980. Professional paper on the Batura Glacier in the Karakoram Mountains. Science Printing House, Beijing.

Key words: Glaciers, Batura, Karakoram.

Z/95. Zimmermann, J.L., Debon, F. & Bertrand, J.M., 1986. The upper Miocene Baltoro granite (Karakorum axial batholith, northern Pakistan): K-Ar dates and cooling history. Terra Cognita 6, p.193.

The Baltoro granite, an intrusion more than 100 km long and ca. 4 to 20 km wide, probably represents the youngest acidic plutonic unit of the composite Karakorum axial batholith. Proposed for a long time from a comparative study of pleochroic haloes in biotite, its Upper Miocene age of emplacement has only quite recently been revealed by isotope dating methods, viz. three internal Rb-Sr isochrons (8.8 ± 0.3 Ma) and ten K-Ar dates (8.5 ± 0.8 Ma). The K-Ar dates have yielded the following results : (1) for three whole rocks : 8.85 / 9.35 / 9.25 Ma, average 9.2 Ma; (2) for three biotites and one muscovite: 7.45 / 8.0 / 8.85 /8.85, average 8.3 Ma; (3) for three K-feldspars : 7.2 /7.85 / 8.95, average 8.0 Ma. I t is suggested that the three average ages (9.2, 8.3, 8.0 Ka) reflect the Cooling - crystal1izaiton timing of the Baltoro magma, from its emplacement (c a. 9.2 Ma) down to the K-feldspar isotope closure. Much detailed work is needed to be done to transform this rough speculative estimate into tested and accurate hypotheses. The Baltoro granite offers a rare possibility: a concrete and full-size approach of the cooling history of a plutonic body.
Key words: Granites, Miocene, Karakoram.

Z/96. Zuber, R., 1914. Beitrage zur Geologie des Punjab. Jahrbuch der Koniglich geologischen Reichsanstalt, 64, 327-356.

Key words: Geology, Punjab, India.